THE
POPULAR SCIENCE
MONTHLY.

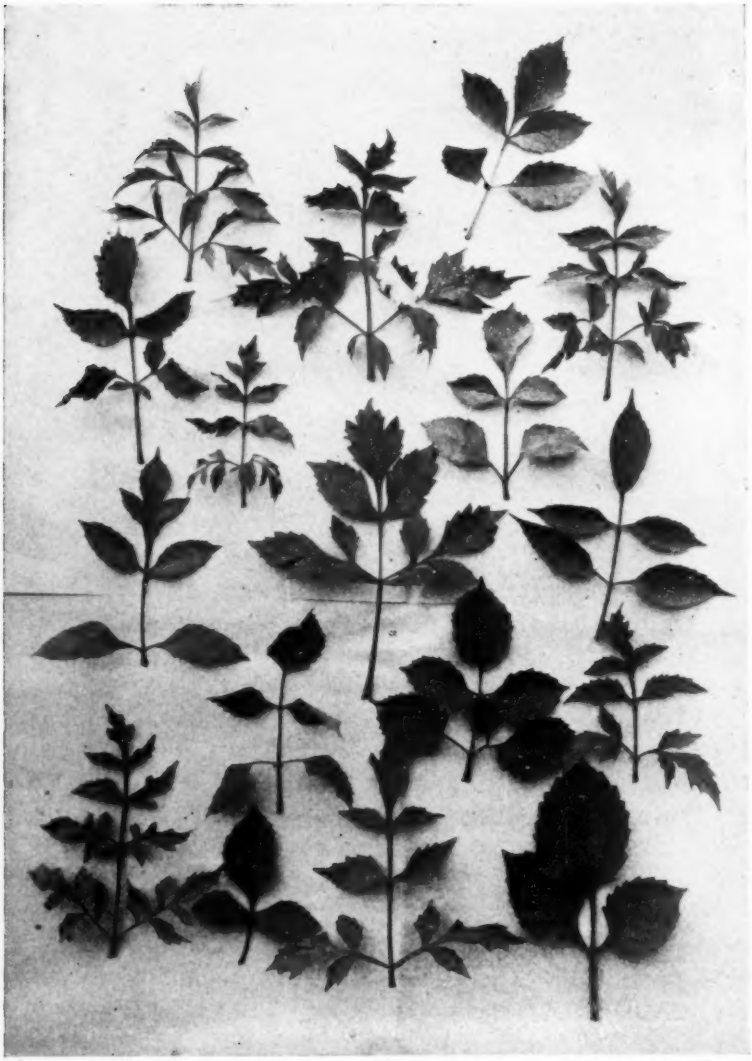
JANUARY, 1905.

SOME EXPERIMENTS OF LUTHER BURBANK.

By President DAVID STARR JORDAN,
LELAND STANFORD JUNIOR UNIVERSITY.

MR. LUTHER BURBANK, of Santa Rosa, California, is doubtless the most skilful experimenter in the field of the formation of new forms of plant life by the process of crossing and selection. He is the creator of many of our most useful plant forms: roots, nuts, fruits, grains and grasses, as well as of many of our most beautiful flowers. His methods are the practical application of the theories of Darwin and his followers, and to a degree wholly exceptional among plant breeders, Mr. Burbank has kept in touch with most modern work in the field of bionomics, and very much of his time and energy is devoted to experiments of scientific interest not likely of themselves to yield immediate practical results. In the nature of things, the demands of his work, and the necessity for the sale of new forms produced by him, have prevented the keeping of detailed records of his work, although steps have been taken toward the provision of explicit records in the future. For the rest, Mr. Burbank's success in practical achievement gives weight to his views on theoretical questions.

The present writer has recently at different times spent three days in Mr. Burbank's company at his gardens at Santa Rosa and Sebastopol, keeping note of things seen and of Mr. Burbank's views concerning them. In this paper, selections are made from these notes, the forms of plants referred to having been examined by the writer and the report of explanations having been verified by Mr. Burbank. All quotation marks refer to conversations with Mr. Burbank, the statement of which Mr. Burbank has verified or corrected. The accompanying illustrations are all from photographs by Mr. Burbank.



SAMPLE LEAVES OF COMMON GARDEN DAHLIA (*Dahlia variabilis*), SHOWING ORDINARY VARIATION *within* A SPECIES WHEN UNDER CULTIVATION.

The process of formation of new types may be grouped under four heads: selection, crossing, hybridization and mutation (or saltation). The process of artificial selection is used in all cases, those varying strains likely to prove useful being preserved, the others destroyed. The word 'crossing' may be advantageously used for the mingling of strains within a species, and 'hybridization' for the breeding together of members of different species. The name 'mutation' (or preferably 'saltation') is applied to sudden changes of characters for which no immediate cause is apparent.

Not many of Mr. Burbank's results are due to unassisted selection, as the processes of crossing and hybridization save time by the increase of the rate or degree of variation. There is, however, no evident limit to the results to be obtained by simple selection. New and permanent species of wheat have, without a shadow of doubt, been produced by selection alone.

In the California poppy (*Eschscholtzia californica*), stripes of crimson are never seen on the inside. Mr. Burbank once found a seedling in which the outside crimson had struck through like a crimson thread which had been misplaced. In other generations, by selection, this red was more and more increased, until finally out of it is developed a crimson poppy, of which Mr. Burbank has now many specimens, seeding more or less true to the type. The 'Shirley' poppy (*Papaver rhœas*) is well on the way to blue by selection.

It is questioned whether competition in minor details, or 'intra-specific selection,' can form species permanent as wild species are. As to this, Mr. Burbank notes that the cultivated species produced after the fashion of his crimson eschscholtzia 'have a very brief history compared with the wild species, and, moreover, they are constantly being placed in a new environment by man, being influenced by new soils, new climates, new fertilizers and the like.' "Breeding to a *fixed line* will bring fixed results. Man's desultory breeding is brief, the struggle for existence is mostly absent, and new ideals and new uses are required instead of ability to endure under natural conditions. Man's efforts at selective breeding are fluctuating, with frequent saltations."

Dr. De Vries notes that in the common sugar beet, which is a biennial species, there are from one to ten per cent. of plants which bear seed the first year. None of these is ever chosen for seed, and yet the long-continued process of natural selection has never succeeded in rooting them out. As to this Mr. Burbank observes: "This long-fixed tendency to insure continued existence in the past is not yet bred out. Analogous to this is the tendency in flocks to produce black sheep, and the appearance of zebra stripes on horses—ancestral traits not yet bred out."

From the pale yellow Iceland poppy (*Papaver nudicaule*) are developed white, yellow and orange forms, and some with striped petals and a strong tendency to become double. Selecting the Iceland poppy for size alone, flowers three and one-half inches across have been developed. A large scarlet poppy, *Papaver glaucum*, closes its two inner petals when a bee or two have entered, shutting in the bees, which buzz angrily and cover themselves with pollen until they are set free. If not visited by bees, the flowers *do not close.*

A wild form of one of the Liliacæ, *Brodiæa terrestris*, was made white by selection of the palest among the pale wild ones. *Brodiæa*

lactea taken from the high Sierras where it is a dwarf, becomes, after two years of cultivation, more than twice as high as the original stock, but not nearly as high as the same species grown in the valley.

"Crossing is done to secure a wealth of variation. By this means we get the species into a state of perturbation or 'wabble,' and take advantage of the 'wabbling' to guide the life forces into the desired habits or channels. The first crossing is generally a step in the direction in which we are going, but repeated crossing is often necessary and judicious selection always necessary to secure valuable practical results. Crossing may give the best or the worst qualities of the parent, or any other qualities; and previous crossings often affect the results."

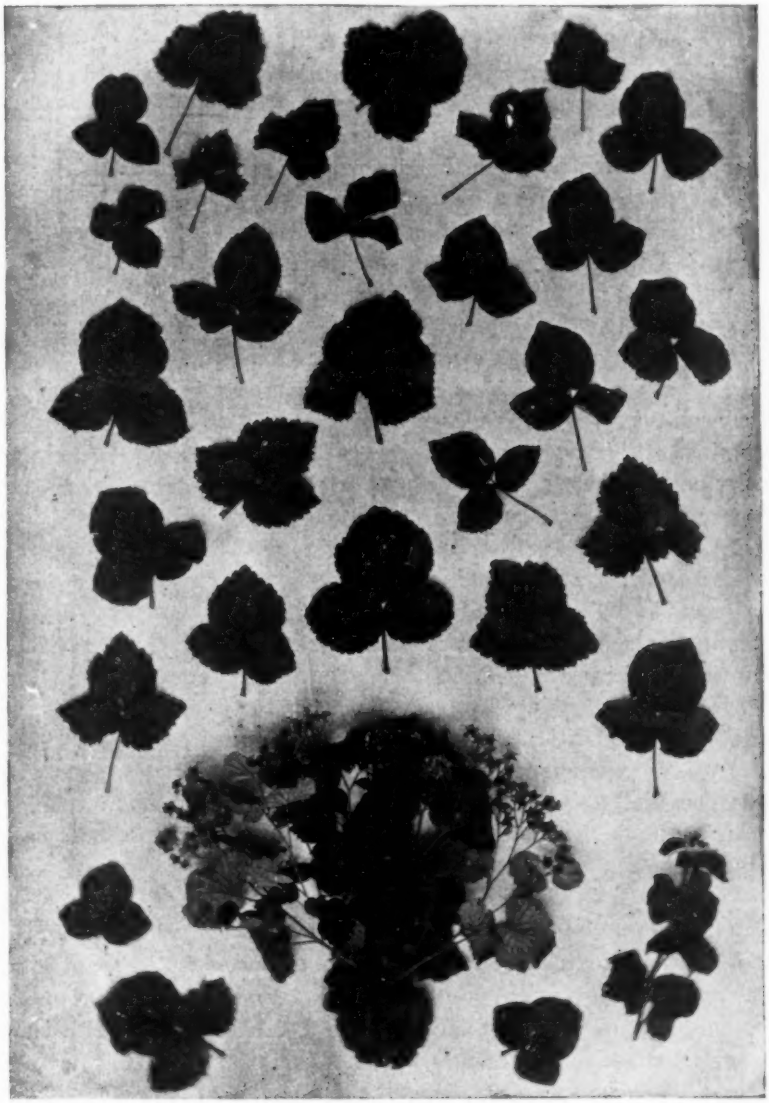
Primus, THE FIRST FIXED RUBUS SPECIES ARTIFICIALLY PRODUCED.

"Hybridization differs from ordinary crossing only in degree. A species is only a race which has assumed greater fixity. The purposes and results of crossing within the species and of hybridization of different species are essentially alike. The formation of the new individual by the sexual relation of two parents is in itself a species of crossing, giving each new individual in its degree new traits or new combinations."

"Bees and other insects, as well as the wind, cross plants, but they do not work intelligently, therefore rarely to any advantage economically to man. No mechanic could invent such devices as those which tend to prevent self-crossing in plants. *All evolution and improvement are dependent on crossing*, therefore nature has produced more wonderful devices for this purpose than for any other."

"Mutations, or saltations, are often found; that is, fixed forms springing up, generally from unknown causes, forms which are not hybrids, and which remain constant; as, for instance, colored flowers which yield white forms, these yielding white constantly in their progeny. *These mutations can be produced at will* by any of the various means which disturb the habits of the plant. It comes out when the conditions are ripe. New conditions bring out latent traits. I should expect mutations to arise in the American primrose and most other plants under wholly new conditions. Extra food or growth force as well as crossing favors variation, as does abrupt change of conditions of any kind. Five or six generations will usually fix a mutation. Sometimes it is fixed at once."

"On the average, perhaps about six generations fairly fix a variation, but this varies greatly, depending upon previously acquired hereditary tendencies. Bringing a species into a new environment dis-



LEAVES SHOWING A NUMBER OF STRAWBERRY-RASPBERRY HYBRIDS AND A CLUSTER OF THE BLOSSOMS.

turbs its fixity. Rich soil especially gives rise to variations in growth which seem to be new, and by repetition become inherently fixed. Sometimes ancestral states are brought about by good soil; sometimes

(perhaps oftener), also, by starvation; *new* variations oftenest by rich soil and general prosperity. *There is no evidence of any limit in the production of variation through artificial selection, especially if preceded by crossing.* Mutations are probably due to the sudden appearance of latent tendencies in new combinations, producing novel effects analogous to new chemical combinations."

"*Mutation is not a period, but a state* induced by various hereditary and external conditions. It is not by any means certain that there is any period in the life-history of the species when it is more subject to mutation than at other times, other conditions being similar. By crossing different species we can form more variations and mutations in half-a-dozen generations than will be developed by ordinary variation in a hundred or even a thousand generations."

"The La France and some other roses, as well as dahlias, callas and many other plants, every once in a while throw out, on some particular year, a number of unusual sports in various localities. This is probably a matter of season, the forces outside bringing about parallel mutations. The evolution of species is largely dependent on crossing the variations contained within it. Forms too closely bred soon run out, because generally only by crossing does variation appear. It is of great advantage to have the parents a certain distance apart in their hereditary tendencies. If too close together there is not range enough of variety. If too far apart, the developed forms are unfitted for existence because too unstable. *Correlated changes work together to produce the effect of mutations.* Environment effects a permanent change in species by selection of those which fit it or by producing changes in individuals which are better equipped to survive. *Heredity is the sum of all past environment,* conditions both latent and apparent. Latent traits often arise when circumstances make them possible. Environment of a lifetime does not necessarily or usually appear in another lifetime, but *continues in the same direction* and will strike into the nature of the plant in time. We may refer to Emerson's remark on the 'baking into the picture of the pigment laid down by environment.' Selection is 'cumulative environment.' Fortuitous variations occur everywhere. They come up all the time, from past environments, past heredity and present opportunity. No two individuals are alike. Where there is a marked tendency in one direction, we have the case of a persistent effect of environment. Monstrosities are engorgements of force. They are generally a thousand times more likely to develop another sort of monstrosity than normal individuals are. You are likely to get from sports and monstrosities either extreme of variance. *They do not, however, maintain themselves, because heredity pulls back their descendants.* A wide variance is more easily pulled back than a slight variance. There are cases where the monstrosity might pull back its species.

This is more likely to happen if the forces of natural or artificial selection were in its favor. There are many cases where the variant in minor points is prepotent and outweighs the original stock. Monstrosities produced by crossing often perpetuate themselves as well as the species does."

"One difficulty with the mutation theory of Dr. De Vries, in my opinion, is lack of sufficiently wide experimentation. Fuller investigations will certainly show that the 'sports' or 'chance' variations come under the same law as that of 'fluctuating' variations, mutations being only fluctuating variations carried beyond the critical point where past fluctuating variations can not withstand the accumulated forces without disintegration, thus bending them in a new direction."

"Professor Hubrecht is certainly in error in stating that the mean fluctuations can not be carried into the extreme or 'sport' variations by selection. Professor Hubrecht speaks of two divergent processes, 'fluctuating variations' and 'mutations,' which he says: 'Darwin has not sufficiently kept separate.' They are not separate; one is only a tendency toward the other, and which continued, though latent, may, or will, at last become dominant, so as to swing the fluctuating variations fully out of the old orbit into the 'mutation' or 'sport' condition. Radical changes of environment for a series of generations will produce a tendency to sport, but hybridization will bring it about far more abruptly, and for practical plant or animal breeding or for scientific study of all these variations, far more satisfactorily."

"The misunderstanding evidently comes from not having a clear knowledge of latent and dominant hereditary forces. A knowledge of these explains the whole matter and makes harmony between Darwin and Wallace, leaving Professor De Vries's careful experiments good, but coming to different conclusions on the results."

"Professor Hubrecht also states that 'now for the first time—forty years after the appearance of the 'Origin of Species'—the actual birth of a species has been observed by him.' As I have produced several good species by hybridization, as good as nature herself has produced, and as others have done the same by selection alone, the above sentence is hardly true. But as before stated, hybridization followed by selection is the shortest plan by which valid new species can be produced. In other words, the *'period of mutation' can be produced at will!*"

"The mutation theory of the origin of species seems like a step backward towards the special creation theory, and without any facts as yet adequate to support it as a universal theory, however valuable and suggestive the experiments of Dr. De Vries may be."

"There is a remarkably close analogy between hybridization and grafting. Bringing over from France a prunus (*P. mirobolana* var.

pissadi), of which there was no other specimen in America, it was grafted on to the Kelsey plum, a variety of *Prunus triflorus*. The graft itself did not bloom, but the presence of the graft brought about in the tree a cross of the two species. This is the only case known to me in which the graft affected the reproductive system of the plant, forming a cross between forms which had never crossed. Many hundred descendants of this cross are now living. Darwin accepted with reservations the account of the graft hybrids in potatoes, and there still remains some doubt of reliable testimony of the supposed fact. He also speaks of a now well-known graft hybrid of a yellow and purple cytisus, which is perhaps the most remarkable fact in this line on record."

DIAGRAM SHOWING THE ZONE OF LIFE AND PARALLELISM OF RESULTS IN CROSSING AND GRAFTING. (L. B.)

Utter refusal to unite under any circumstances, either by crossing or grafting. (Outside of zone of possible union.)

	Pollen acts as a poison.	Grafts blight and die as if poisoned.
Crossing by Seeds.	Union partial, mosaic or temporary; seed rarely produced; seedlings generally inherit tendencies and qualities of one parent only; second or later generations revert fully.	Grafts often form a temporary union but are not in a normal condition. Avoided by nurserymen and planters with great care, as results are often disastrous to the grower.
Crossing by Seeds.	Union free; seedlings show unbalanced condition, varying widely; often unusually vigorous; best condition for scientific or natural selection. Good qualities can be made permanent to the race.	Mendelian or Mutative State. Grafts unite readily but separate under unusual stress—drought, overbearing, lack of nourishment, etc. Avoided by nurserymen and planters. Crossing by Graft.
Crossing by Seeds.	Unite freely; seed of superior germinating quality produced abundantly. Seedlings normal with ordinary amount of variability.	Unusual Variation. Grafts unite readily, thriving well; sometimes better than when grafted on their own stock. Crossing by Graft.
	Ordinary plant life as oftenest met with.	Normal. Grafts unite and thrive as we oftenest see them.
	Self-fertile; seed produced, but as there are very limited opportunities for profitable variations, this state ultimately ends in	Grafts grow on their own roots.

EXTINCTION.

All these varying states shade off from one to the other, with few hard and fast lines of separation.

"In some directions the strains of heredity are much more unbalanced than in others. An impulse from outside forces may bring about new combinations. This is illustrated by De Vries by a ball with many facets, which, if lightly touched, will return to its original position, if vigorously touched will turn over. Burbank once crossed a pole bean (*Phaseolus vulgaris*) with a lima bean (*Phaseolus lunatus* var. *macrocarpus*). There was no visible effect in the appearance of the pod or the bean, but, when planted, each bean developed a cotyledon, part of one species and part of the other. The lima bean represented the end of the cotyledon, and was united to the lower part by serrated edges; below was the smaller and striped cotyledon of the pole bean. The cotyledons finally parted at the joints between the two, the upper portion falling off, as is often the case with grafts which are uncongenial. The forms were tremendously vigorous, but all came back to the common pole or horticultural bean after the second generation, as though it were an uncongenial graft hybrid, the alien portion being finally entirely rejected. It often happens in grafting, that the branch will be united thoroughly at the point of grafting, but in great stress, as the overbearing of fruit, the grafted portion will separate and entirely fall off."

"In one sense, hybridization is only a mode of grafting, both being a more or less permanent combination. The different results from hybridization are shown in the diagram below."

"Where the plants are very different, having a different line of descent, and consequently different structure, there will be no hybridization at all. From this we have every gradation to the point where the individuals are very closely alike, and here we have scarcely any variation at all in the progeny, a condition which favors extinction. Again, in grafting, we have every intergradation between total inability to unite and absolutely perfect blend."

"Sometimes a graft strengthens a plant by increasing the body of foliage and thus strengthening the roots. Grafting a Japanese pear on the Bartlett pear will give the latter new life through the increase in the foliage, which gives material for root action and further extension."

As illustrations of the results of crossing and hybridization, the following notes were taken on plants in Mr. Burbank's gardens:

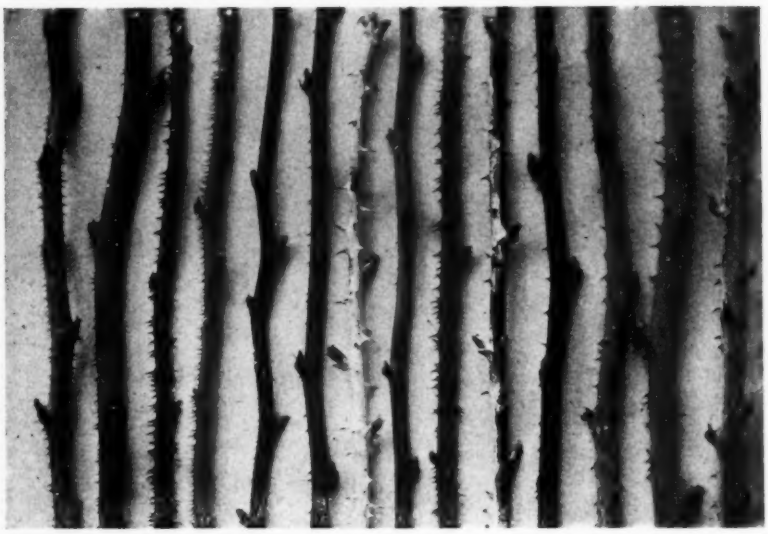
In the beginning of his work Mr. Burbank crossed all sorts of beans and had a half acre of them. Some climbed to the height of twenty or thirty feet, producing all sorts of pods—some with pods long and slender and stems so short that the pods doubled up on the ground. These forms could have been fixed in time, though the variations were unusually persistent and very amazing in their variety and abundance.

Crossing the red and white pole bean, two or three of the beans grew large and bore striped pods, the beans themselves being jet black.

From this cross many varieties were developed having all the colors known in beans.

The results of selection are often so simple as to form a mathematical rule, as in the case of Mendel's peas, which holds good with the tribe of peas (*Pisum*), but not generally with others so far experimented on. At other times they are so complicated that to follow them requires the highest skill, or may be utterly impossible.

A rubus (*R. cratægifolius*) from Siberia has fruit the size of a large half pea, brownish, seedy and tasteless. Hybridizing with the California blackberry (*R. vitifolius*), some of the hybrids have the best qualities of both berries combined, and a perfect balance of characters. Out of over five thousand second generation hybrid seedlings, every one is true to the seed. This refers to the Primus blackberry, which is now fully as true a species as any classified species of *Rubus*.

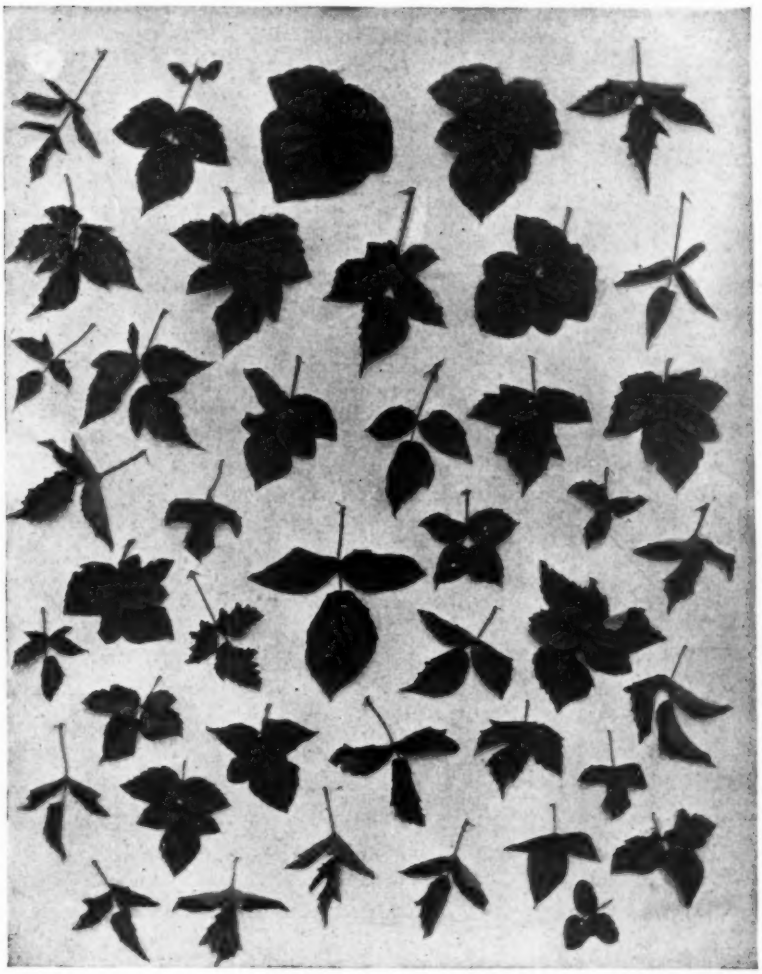


STEMS OF BLACKBERRY-RASPBERRY HYBRIDS.

The raspberry has been hybridized with a strawberry: the results were thornless plants with trifoliate leaves looking like a strawberry plant and sending out underground stolons like the strawberry. At last, however, the plants send up canes three to five feet high bearing panicles of flowers more profuse in number than those on either parent. After flowering the plant never produces a berry, the fruit forming a small knob, with no effort at maturity.

In the hybrid of the strawberry and raspberry, the resultant plants bore three or four times as many flowers as the raspberry, seven or eight times as many as the strawberry.

Tendencies strong in the parent, even though for a time latent,



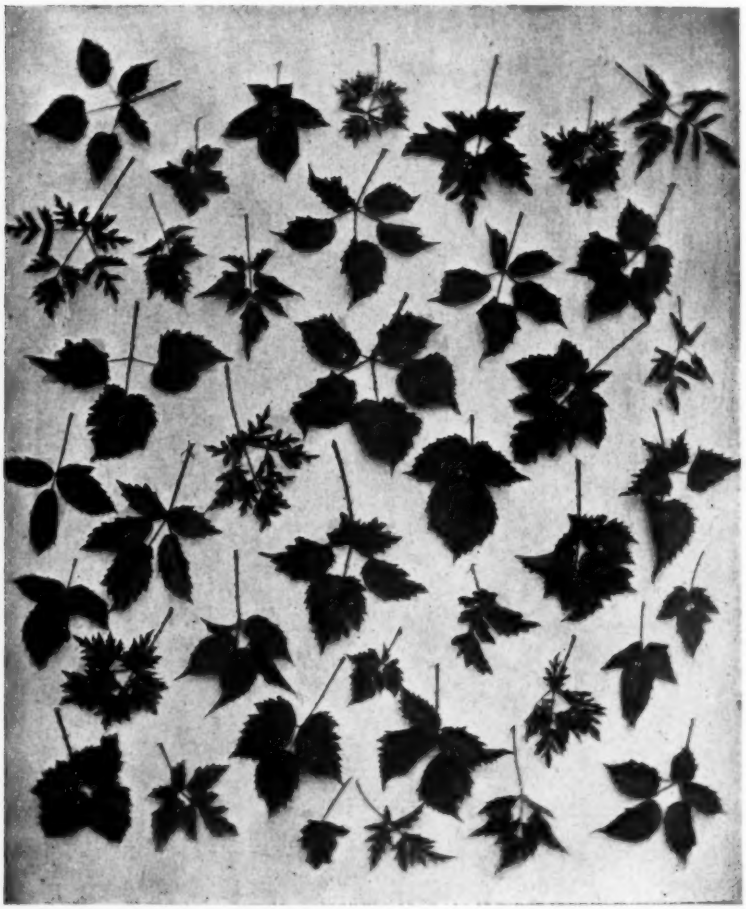
LEAVES OF BLACKBERRY-RASPBERRY HYBRIDS.

usually come out strong in the descendants. Ordinary hybrids of forms closely related generally form a perfect blend from both parents. When the parents are far apart all sorts of variations occur, the so-called Mendelian condition being one phase of the results.

Hybridizing the iceberg white blackberry with the Cuthbert raspberry develops a plant with foliage and growth midway. About half the plants bear fruit which is red like the raspberry, about half bear fruit which is white like the iceberg blackberry; the quality is midway between the blackberry and the raspberry. In the crossed fruit (first generation) the flavor is not superior, but it is quite intermediate between blackberry and raspberry. The form of the receptacle is intermediate. Some of the fruitlets separate at the base, but not above.

In crossing it makes no difference which sex is taken as the male parent; it all depends upon the hereditary tendencies of the sex.

Crosses of wild species yield results similar to those from cultivated species, but the latter are more available. The white blackberry is a wild variation crossed with the Lawton for size and vigor; the result is a



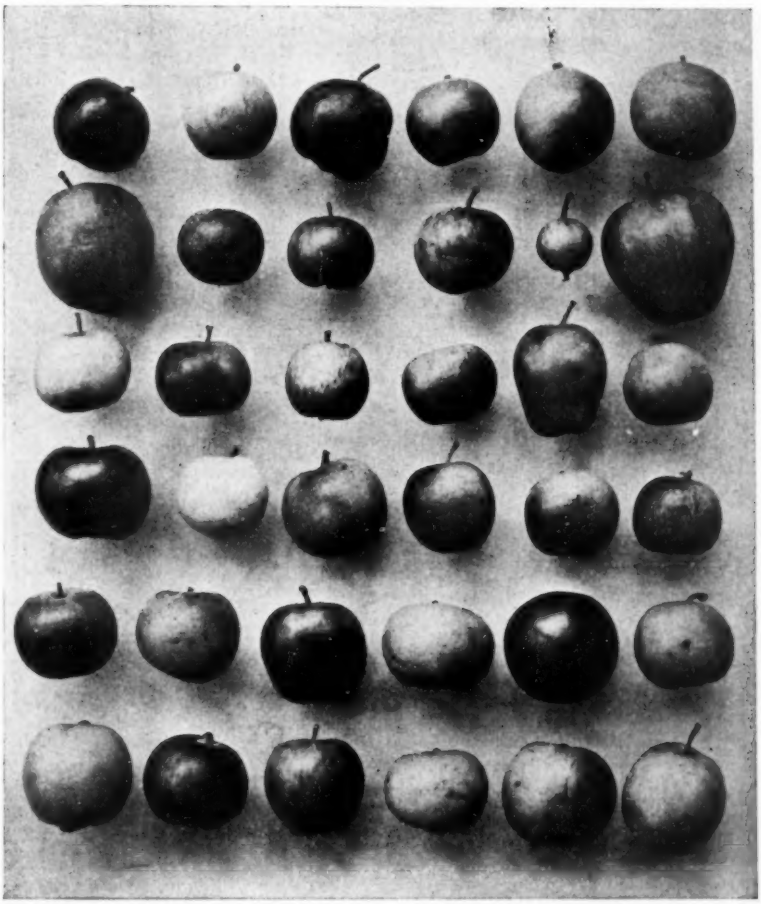
LEAVES OF A BLACKBERRY HYBRID, ALL GROWN FROM SEED OF ONE PLANT.

much clearer white than the wild one, larger, and very much more productive, in these respects fully equal to its staminate parent, the Lawton.

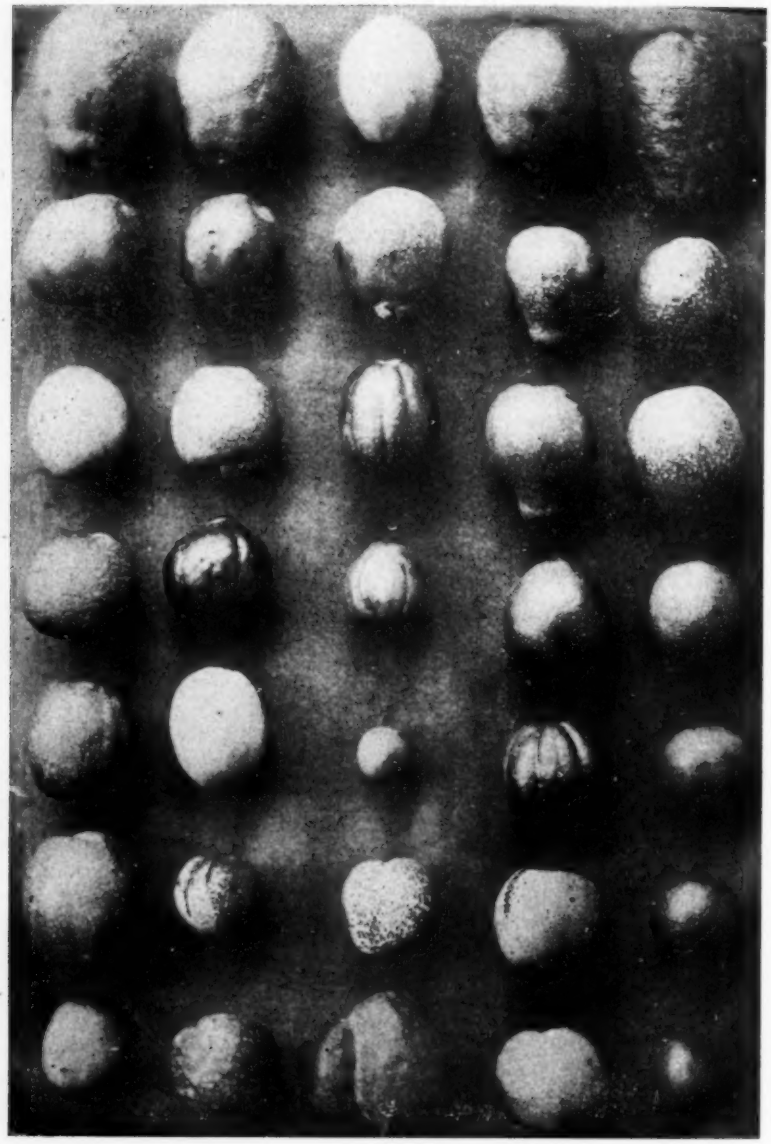
Apples brought up from the south temperate zone are entirely confused here, yielding leaves, buds, flowers and small apples at various seasons. One of these apples in time, however, became adapted to the conditions and developed into one of the best apples in Mendocino County.

"Animals or plants changed by transference from one country to another never quite go back to the old conditions, even if placed in them again, as hereditary tendencies acquired under the new environments, even though latent for many generations may be called forth again under favoring conditions. Exceptions seem to be as important as the rules in this work. Nature leaves so many loopholes that there is almost no rule without exceptions. She does not tie herself up to any unvarying conditions. Adaptability is more important than perseverance."

A blackberry plant with an immense mass of fruit developed from a seedling from the Himalayas. One plant covers 150 square feet, is 8 feet high, and has a bushel or more of fruit. This is only a young, small plant; when full grown this variety is many times larger.



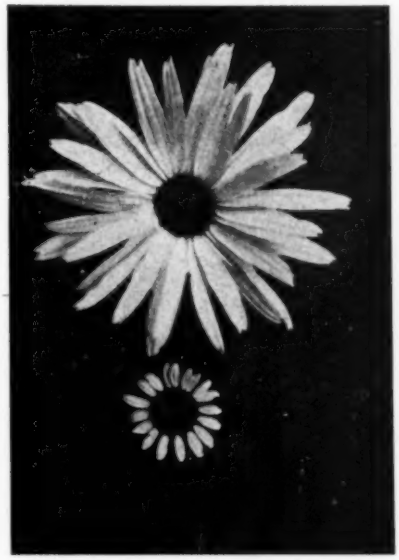
APPLES—ALL SEEDLINGS FROM ONE VARIETY, 'THE EARLY WILLIAMS,' SHOWING ABOUT THE NORMAL VARIATION OF APPLE SEEDLINGS.



SEEDLINGS OF JAPANESE QUINCES, SHOWING NORMAL VARIATIONS.

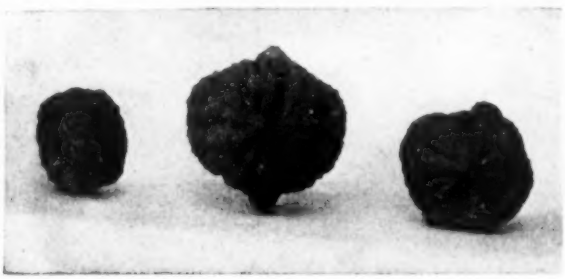
A purple larkspur reared by Mr. Burbank is produced by crossing a native blue with a native scarlet, the color being entirely a blend. The blackberry was crossed with apples and with all the various rosaceous plants. Over five thousand plants were produced. The apple-blackberry cross came out essentially apples in foliage and growth, though raised from blackberry seeds. Only two of them ever bloomed, all were thorn-

less, one of them bearing rose-colored flowers. From the mountain ash and blackberry a salmon-colored fruit with no thorns and no albumen in the seed was developed. A hybrid between the English and the black walnut grows fully four times as fast as the English walnut; it bears little fruit. The seedlings from the fruit produce some English, some black, and some hybrid walnuts, and not rarely entirely new forms. Crossing often brings about great vegetative life at the expense of reproductive life, or the reverse. The young (second generation) hybrids of the black walnut and the English walnut show very great variation in their leaves, resembling neither parent. The hybrids of the English and California black walnuts are most rapidly growing trees and unusually productive. The first hybrid, of the English with the Japanese walnut, *Juglans sieboldi,* is largely like the Japanese in the nuts, but rather more like the English in foliage, the second generation being very variable as usual.



THE ORIGINAL AND IMPROVED (SHASTA) DAISY.

By crossing types already crossed, we may often bring out the original stock which had been lost in cultivation. The English walnut has usually five leaflets, the black walnut fifteen to nineteen. The first



JAPAN WALNUT. RESULT OF CROSS OF THE TWO. ENGLISH WALNUT.

generation hybrid has eleven, with a fragrance to the leaves that no original walnut has. This tendency or trait is just as real as any other. The American walnut (*Juglans nigra*) and the California black walnut (*J. californica*) are closely related species and when hybridized yield fruit of very large size and in enormous quantities.

Descendants of hybrids usually revert to either one or the other parent or break up in all directions. A cross of the eastern black walnut (*Juglans nigra*) with the California nut (*J. californica*) yields a hybrid which is a very great grower. From the seed of this tree a surprising variety of mutations are developed, not only resembling

LEAVES FROM SECOND GENERATION SEEDLINGS FROM CROSS OF COMMON PERSIAN WALNUT (*Juglans regia*) AND CALIFORNIA NATIVE WALNUT.

every possible combination of both parents but numerous strange forms. In fact, among about two thousand seedlings now alive, almost every type or form of walnut foliage may be found. There are startling variations in size, form and number of leaflets, in the size of the plant, in the serration of the margins, in the degree of roughness of the surface, in every feature in which one walnut may differ from another.

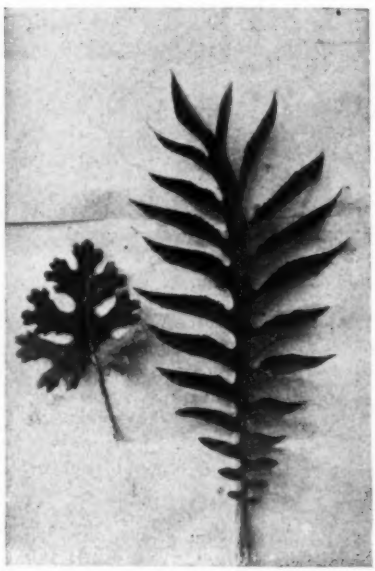
HYBRID MESEMBRAYNTHEMUM.

Some time since, a hybrid mesembryanthemum was developed, and lasted for four years, forming an attractive plant with a profusion of white flowers. Then all individuals, whereever located, died at once, doubtless because conditions were adverse: but there was no visible cause of soil, of insect pest, of fungus or of climate. These plants all died from the root up. A hybrid of petunia and nicotiana has abundance of flowers and a large vigorous leaves, but the roots are inadequate. A hybrid red poppy is formed by uniting the opium poppy with the oriental poppy. These hybrids bloom every day of the year, while the blooming season of either parent is only a few weeks, but they yield no seed. The seed capsules are developed in great variety, some of them four to six times as large as the capsules of either parent.

Others are scarcely thicker than the stem which bears them, while others are absolutely and completely absent. This hybrid poppy is tall and generally branches like the opium poppy. It is perennial, although its pistillate or seed ancestor is a short-lived annual. This red poppy can even be divided at the root and multiplied like the perennial oriental poppy. These hybrids have generally a dark mark at the base of the scarlet petals as in the oriental poppy; in some the leaves are smoothish and glaucous, as in the opium poppy; in most, deep green and hairy, more as in the other. Many flowers have their stems coalescent with that of the neighboring flower.

SAMPLE OF HYBRID POPPIES.

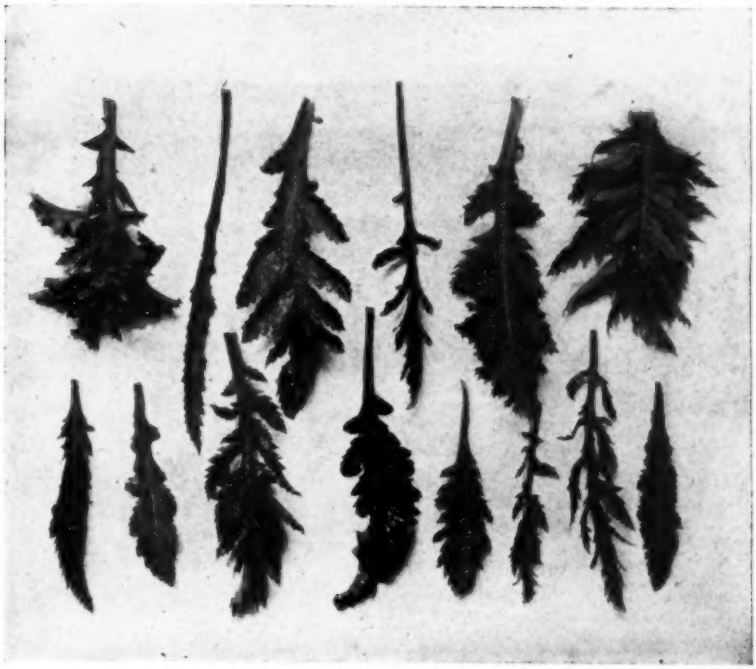
"These second generation hybrid poppy plants unexpectedly all proved to be *perennials,* and are now making a tremendous growth; the clusters of foliage of some of them are fourteen to eighteen inches across already. Among this *second* generation hybrid lot of poppies each single plant seems to be different from every other plant in the lot and strange to say the leaves now resemble not only poppy leaves, but celandine, various thistles, primroses, turnips, mustards and numerous other plants are very closely imitated, showing most astounding variations."



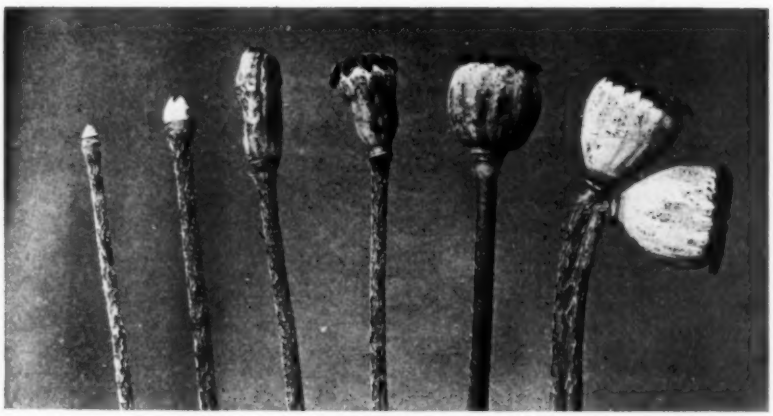
SAMPLE LEAVES OF TWO SPECIES OF BOCCONIA, SHOWING ONE OF THOUSANDS OF CASES OF GREAT VARIATION IN FOLIAGE IN CLOSELY RELATED SPECIES.

The striped amaryllis, *vittata,* hybridized with a Mexican species, *formosissima,* has narrow twisted petals of a very deep scarlet and nearly plain. The leaves are much narrower than in the *vittata,* the stalks more slender, and the plants more profuse bloomers.

Hybridizing crinum with amaryllis develops a plant with a fine



LEAVES FROM HYBRID POPPIES, showing unusual variations in foliage even for second generation hybrids. Blossoms vary about as much as the leaves—the habits of the plants also. These are an average random selection from about two thousand second generation seedlings.



CAPSULES OF SECOND GENERATION HYBRID POPPIES, showing series of variations from complete absence of capsules to capsules of unusual size and to double capsules of unusual size. These selected at random from about 2,000 plants. The individual plants which produce these types generally follow them in all the capsules.

flower but no seeds. Crossing the small hardy white calla with a yellow one which is not hardy, develops, with selection, a hardy yellow calla.

A crinum from Florida is hardy but not handsome. Crossing this with a handsome crinum from Mexico, the plants were selected for those which should be both hardy and handsome. The desired qualities of the two species have been combined and other valuable new qualities incidentally developed as regeneration and selection proceeded.

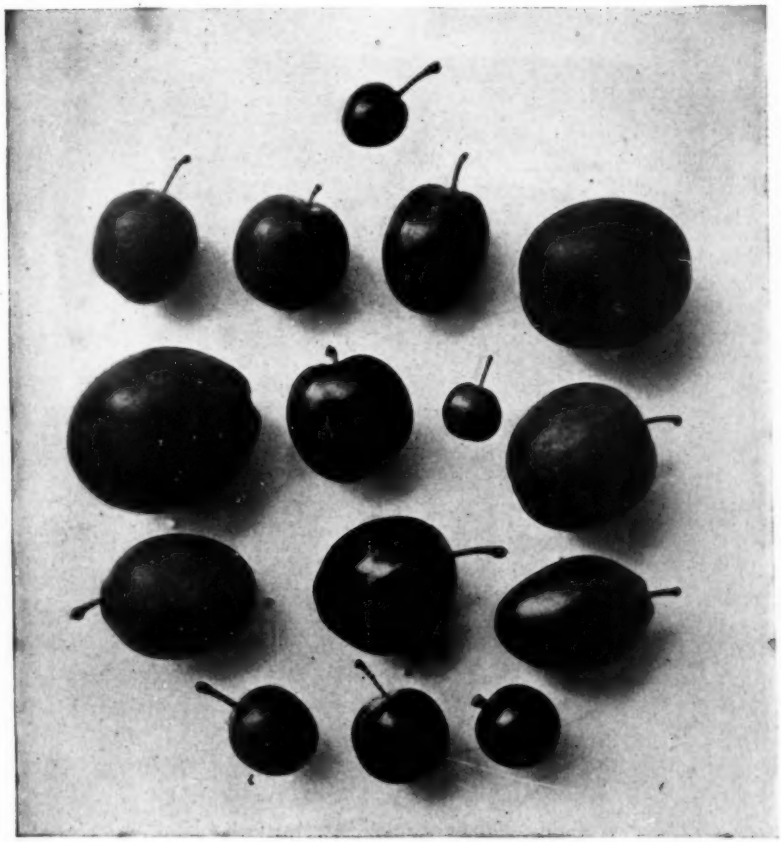
In hybridizing callas, the yellow ones with the white, to form a hardy yellow race, some of the resultant plants have pale flowers, some light yellow, and those chosen are made deep yellow by selection from second and later generations. Both parent plants in this case have leaves blotched with white, and this is found in all the descendants.

Hybridizing the wild flower, *Erysimum arkansanum,* which is yellow, with a native wild white species, resulted in the first generation a perfect blend of yellow and white; with a second generation the species separate completely, about five per cent. of those examined being yellow, the other ninety-five per cent. white; white dominant. With a hybrid *Thalictrum,* seed pods are developed more abundantly than with either parent, but the seeds are not viable.

We may expect variations in form, size, color, quality, fragrance, vigor or any other characteristic. To get variation in any one direction is to open the door to anything else. Hybridizing the Japanese quince with the common quince, we have large-leaved seedlings which look quite different from the parent (common quince). The final result is a seedling looking like the Japanese quince, without the power of continued growth (too wide a cross to blend permanently or profitably).

Some of the black raspberries when hybridized with some of the blackberries usually die when the time comes to bear fruit. Many hybrids perish under the stress of reproduction. The *Amaryllis vittata* is now eight to eleven inches across, being nearly four times as broad as before the work of selection for size was begun, and with vigor and freedom of growth and bloom amazingly increased. On a strip of poor land it grows very small, with narrow leaves and slender flowers, but on the same poor land some of the hybrid variants grow very large and pay no attention to the soil. A variant of *Ampelopsis quinquefolia* has very large leaves, highly colored in the fall, but no fruit. *Mimulus tigrinus* of Europe has very many variations. Its flowers are yellow, with patches of orange and other colors. When crossed with some of our native species, the seedlings are greatly improved in all respects, even in blooming, yet rarely produce seeds.

It is generally much easier to develop variations in seedlings from variegated flowers than from those of solid color (the variegation shows a lack of complete amalgamation). A double mimulus is formed of the *hose-en-hose* sort. One hybrid poppy produces an abortive flower



ORIGINAL WILD STONELESS PLUM AT THE TOP AND 14 OF ITS SEEDLINGS WHEN CROSSED WITH THE FRENCH PRUNE BELOW, ABOUT ½ SIZE.

inside the capsule. All seedlings always vary more or less. With the same parent, one fruit may be two and one half or more times the diameter of the other, of a different color, flavor or differing in almost all respects. "There is no prepotency of male or female as such. Prepotency depends wholly on heredity. We can not rely on the stoneless types being prepotent, but a certain number of trees producing stoneless fruit usually come from crossing them with those having stones. The prepotency to produce a stone, or a half stone, having been more thoroughly fixed by ages of stone-producing trees, will perhaps be about ninety-nine times out of one hundred. But other things being equal, there is absolutely no balance in favor of either sex. This may be set down as fixed."

With plum-almond crosses there is every kind of variation in the flowers. Some have all stamens, some have many petals or none, some never open, and some have pistils only.

The Climax plum is a cross of the bitter, flat, tomato-shaped Chinese plum, *Prunus simoni,* and the Japanese plum, *Prunus triflora.* The Chinese plum produces almost no pollen; hardly a grain of it is known, not more than one could put in his eye without feeling it; but the whole fruit shipping industry of the world has been changed by this hybrid plum (Climax) produced by it. With many crosses of many things it is certain that forms of great importance will come out every year, though never in profusion.

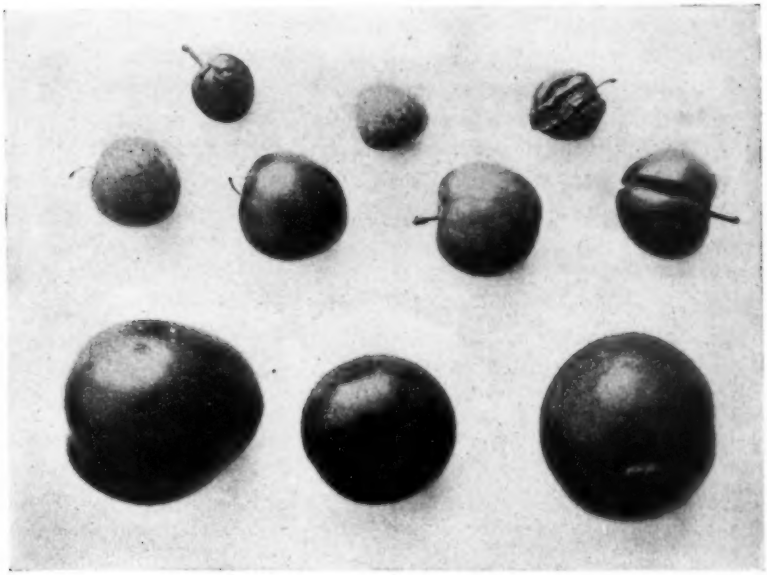
ORIGINAL AND IMPROVED BEACH PLUM.

In developing a spineless cactus for stock-feeding, selections were made from the three hardy northern species, *Opuntia rafinesquii, O, mesacantha* and *O. vulgaris;* these were crossed with *O. tuna, O. ficusindica* and with a small opuntia from Central America, almost thornless.

The cactus has smooth cotyledons, but the first bud is covered with thorns. These thorns have also been eliminated by selecting the smoothest individual seedlings without crossing. Crossing in this case generally interrupts the process, as it brings out well-fixed ancestral traits, but later, to combine the best qualities of several species, crossing and selection must be resorted to. Examples seen were shoots of the original stock, prickly; the second generation, slightly prickly; the third, without thorns; and later the spicules even within the substance of the cactus have been removed so as to make the cactus very excellent food for cattle. This will have very great value in the arid regions. Some cacti lose the thorns on the plant but retain them on the fruit; others *vice versa.* By crossing and extensive and intensive selection a cactus may be improved in various ways besides being deprived of thorns and of the internal spicules in six or less generations; these, by means of cuttings, may be multiplied rapidly to any extent, but the process, to be complete, generally takes longer. This thornless cactus should prove of very great value in the development of desert regions as Arizona or Sonora, as the quantity of food produced per acre is enormous.

The Bartlett plum has the flavor of a Bartlett pear, but even more strongly developed. The 'rice seed' plum has extremely small seeds. The stoneless plum is a cross of the French prune with a wild plum having the stone almost eliminated by a fortuitous variation. The result thus far is a great number of stoneless plums of good size, but in flavor inferior to the best cultivated ones. These are being crossed again to improve the flavor, and new selections made.

Crossing the Japan and the New England chestnut (*Castanea*



TEN VARIETIES OF PLUMS GROWN FROM THE SEED OF THE BURBANK PLUM CROSSED WITH THE APRICOT PLUM, SHOWING VARIATIONS.

japonica and *C. americana*), the trees, leaves, growth and nuts are midway; second generation and later generations as usual show more varied combinations and variations. To breed the burrs off from chestnuts is dangerous, because it allows the birds to get in at the nuts. The

BED OF SEEDLINGS FROM SPINELESS CACTUS, SHOWING HERE AND THERE REVERSION TO THE ORIGINAL SPINE FORM.

burr is originally intended to keep off the birds. In developing a superior variety of the Persian (often called English) walnut (*Juglans regia*), the shell was made too thin, so that the birds could break in. It was necessary to make new selections and crossings to thicken the shell and still retain its other superior qualities.

THALLUS AND FRUIT OF SPINELESS CACTUS.

The Pierce grape was a bud sport from the Isabella, producing much larger fruit. This bud sport remains constant. All the seedlings even from it are similar to the Pierce grape, following the bud sport (*Pierce*) and not reverting to the real parent form of the Isabella. Some ripen early, some late; some are pale, and some are black; but all resemble the Pierce more than the Isabella. Cultivating a choke cherry, the seeds all from one parent tree, many variations are found, although the soil in which they are placed is uniform. Among them was found one variant less bitter than usual; others earlier or later ripening and with larger or smaller fruit or leaves, and an almost bewildering number and variety of other variations. A peach-almond cross often develops a tree as large as ten peach trees or almond trees of the same age. Sometimes a similar cross with different individuals of the same species will produce opposite or totally different results, owing to past heredity, either recent or far back. Crosses are sometimes more vigorous than either parent and more than any descendant, but other cases are just the reverse. The more variant crosses are often less vigorous, and sometimes yield seedlings that can not exist. Sometimes all die in the fruiting season. A peach named 'Quality' is one of the best peaches extant—a cross of the Muir and the Crawford. A cross of the nectrine and peach also produces variant types of value. In some hybrids of petunia and tobacco, the roots fail while the tops may be of unusual vigor. These individuals can only be kept alive for any length of time by grafting, another instance—if other were needed—of the parallelism of crossing and grafting.

THE PLUMCOT—AN ABSOLUTELY NEW FRUIT.

"A character may be latent through many generations or centuries,

appearing when the right cross brings it out; or it may appear under specially favorable or peculiar conditions of growth."

According to Burbank, "the facts of plant life demand a kinetic theory of evolution, a slight change from Huxley's statement that 'matter is a magazine of force,' to that of matter being force alone. The time will come when the theory of ions will be thrown aside and no line left between force and matter. We can not get the right perspective in science unless we go beyond our senses. A dead material universe moved by outside forces is in itself highly improbable, but a universe of force alone is probable, but requires great effort to make it conceivable, because we must conceive it in the terms of our sense experience.'

THE PRESENT PROBLEMS OF PALEONTOLOGY.*

By HENRY FAIRFIELD OSBORN,

DA COSTA PROFESSOR OF ZOOLOGY, COLUMBIA UNIVERSITY. CURATOR OF VERTEBRATE PALEONTOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY. GEOLOGIST AND PALEONTOLOGIST, UNITED STATES GEOLOGICAL SURVEY.

I CONGRATULATE myself that it has fallen to my lot to set forth some of the chief contemporary problems of paleontology, as well as to make an exposition of the prevailing methods of thought in this branch of biology. At the same time I regret that I can cover only one-half of the field, namely, that of the paleontology of the vertebrates. From lack of time and of the special knowledge required to do a great subject justice I am compelled to omit the science of invertebrate fossils and the important biological inductions made by the many able workers in this field. There is positively much in common between the inductions derived from vertebrate and invertebrate evolution and I believe a great service would be rendered to biology by a philosophical comparison and contrast of the methods and results of vertebrate and invertebrate paleontology.

The science of vertebrate fossils is in an extremely healthy state at present. The devotees of the science were never more numerous, never more inspired and certainly never so united in aim as at present. We have suffered some heavy personal losses, not only among the chiefs, but among the younger leaders of the science in recent years; Cope, Marsh, Zittel, Kowalevsky, Baur and Hatcher have gone, but they live in their works and their influence, which vary with the peculiar or characteristic genius of each.

As in every other branch of science, problems multiply like the heads of hydra; no sooner is one laid low than a number of new ones appear; yet we stand on the shoulders of preceding generations, so that if our philosophical vision be correct we gain a wider horizon, while the horizon itself is constantly expanding by discovery.

In discovery the chief theater of interest shifts from continent to continent in an unexpected and almost sensational manner. In 1870, all eyes were centered on North America and especially on Rocky Mountain exploration; for many ensuing years, new and even unthought of orders of beings came to the surface of knowledge, revolutionizing our thought, firmly establishing the evolution theory and

* Address delivered before the Section of Zoology of the International Congress of Arts and Science, September 22, 1904.

appearing to solve some of the most important problems of descent. Then the stage shifted to South America, where an equally surprising revelation of unthought of life was made. We were in the very midst of the more thorough examination of this Patagonian and Pampæan world when the scene of new discovery suddenly changed to North Africa—previously the 'dark continent' of paleontology—and again a complete series of surprises was forthcoming. Each continent has solved its quota of problems and has aroused its quota of new ones. Now we look to central and South Africa, to the practically unknown eastern Asia, and possibly to a portion of the half sunken continent of Antarctica for a future stock of answers and new queries.

Rapid exploration and discovery, however, are not the only symptoms of health in a science; we do not aim to pass down to history as great collectors; we must accumulate conceptions and ideas as rapidly as we accumulate materials; it will be a reproach to our generation if we do not advance as far beyond the intellectual status of Cuvier, Owen, Huxley and Cope as we advance beyond their material status in the way of collections of fossils. We must thoroughly understand where we are in the science, how we are doing our thinking, what we are aiming to accomplish; we must grasp, as the political leader, Tilden, observed, the most important things and do them first.

Paleontology a Branch of Biology.

Let us first cut away any remaining brushwood of misconception as to the position of paleontology among the sciences. I do not wish to quarrel with my superior officers, but I must first record a protest against the fact that in the classification scheme of this congress, in the year of our Lord 1904, paleontology is bracketed as a division of geology. It is chiefly an accident of birth which has connected paleontology with geology; because fossils were first found in the rocks, geology the foster mother was mistaken for the true mother, zoology —a confusion in the birth records which Huxley did his best to correct. The preservation of extinct animals and plants in the rocks is one of the fortunate accidents of time, but to mistake this position as indicative of scientific affinity is about as logical as it would be to bracket the Protozoa, which are principally aquatic organisms, under hydrology, or the Insecta, because of their aerial life, under meteorology. No, this is emphatically a misconception which is still working harm in some museums and institutions of learning. Paleontology is not geology, it is zoology; it succeeds only in so far as it is pursued in the zoological and biological spirit.

In order to make clear the special rôle of paleontology among the biological sciences and at the same time the grateful services which it is enabled to render to its foster science, geology, as well as to geog-

raphy, when pursued in a purely biological spirit, let us employ an imaginary problem. Figure to yourselves a continent absolutely unknown in any of its physical features of earth, climate or configuration; let us imagine that from such an unknown continent all the animals and all the plants could be brought into a vast museum, the only condition being that the latitude and longitude of each specimen should be precisely recorded, and let us further imagine a vast number of investigators of the most thorough zoological and botanical training and with a due share of scientific imagination, set to work on this collection. Such an army of investigators would soon begin to restore the geography of this unknown continent, its fresh, brackish and salt-water confines, its seas, rivers and lakes, its snow peaks, its glaciers, its forests, uplands, plains, meadows and swamps; also even the cosmic relations of this unknown continent, the amount and duration of sunshine as well as something of the chemical constitution of the atmosphere and of the rivers and seas. Such a restoration or series of restorations would be possible only because of the wonderful fitness or adaptation of plants and animals to their environment, for it is not too much to say that they mirror their environment.

At the historic period commemorated by this great exposition of St. Louis when Napoleon concluded to sell half a continent to strengthen his armies, it is true that such a solution of a physical problem by biological analysis might have been conceived by the pupils of Buffon, by Napoleon's great contemporaries Cuvier, Lamarck or St. Hilaire, but the solution itself would not have been possible. It has been rendered possible only by the wonderful advance in the understanding of the adaptation of the living to the lifeless forces of the planet. Finally, it is obvious in such a projection of the physical from the purely biological that the degree of accuracy reached will represent the present state of the science and the extent of its approach toward the final goal of being an exact or complete science. The illustrative figure need not be changed when the words paleozoology and paleobotany are substituted for zoology and botany. We still read with equal clearness the physical or environmental changes of past times in the biological mirror, a mirror often unburnished and incomplete, owing to the interruptions in the paleontological records, but constantly becoming more polished as our knowledge of life and its all pervading relations to the non-life becomes more extensive and more profound.

Such an achievement as the reconstruction of a continent would be impossible in paleontology pursued as geology or as a logical subdivision of geology. The importance of the services which paleontology may render geology as time-keeper of the rocks, or which geology may render paleontology, are so familiar that we need not stop to enumerate them. To emphasize the relation I have elsewhere suggested the phrase, *Non*

paleontologia sine geologia. With other physical sciences paleontology is hardly less intimate; from the physicist it demands time for the evolution of successive waves of organisms, from the geographer it demands continental connections or even whole continents for the passage of land animals and plants. As with geology, what it receives it is ever ready to return in gifts; the new branch of geography, for example, entitled paleogeography, appeals quite as often to the paleontologist as to the geologist for its data.

Problem of the Origin of Fitness.

Naturally the central thought of paleontology as biology is the origin of fitness as the property which above all others distinguishes the living from the non-living. Here the paleontologist enjoys the peculiar advantage of being present at the birth of new characters and watching the course of their development; and to this advantage is attached the peculiar responsibility of observing the birth and course of development of such characters with the utmost accuracy and a mind free from prejudices in favor of any particular hypothesis, with full acquaintance with the phenomena of evolution as they present themselves to the zoologist, the botanist and the experimentalist, and with the philosophical temper which will put every hypothesis to the test of every fact. The laughing remark of Cope on seeing a newly discovered specimen which controverted one of his hypotheses, 'if no one were watching I should be glad to throw that fossil out of the window,' has a serious reality in our often unconscious protection of our own opinions.

The birth of new characters is the crucial point in the origin of fitness. With Darwin himself, with Cope, with Bateson, we do not regard the Darwinian law of selection as the creative or birth factor; by its very terms it operates after there is something of value to select. Forgetting this distinction, some naturalists are so blind as to fail to see that selection is still the supreme factor in evolution in the sense that it produces the most grand and sweeping results as well as the most inconspicuous results in the organic world. Certain of the creative factors can not be seen at all by paleontologists; others, in my opinion, can not be seen by zoologists.

Before looking further into the creation of fitness, let us clear away another misconception, which happens to be of paleontological origin, although paleontologists are not responsible for it. It concerns the history of one of the great theories of the day. Many years ago, Waagen, a German paleontologist, observed that the varieties or minor changes in time (chronological varieties) differ from varieties in space (geographical varieties); that the latter have a variable value and are of small systematic importance, while the former are very constant and,

though seen only in minute features, may always be recognized again. These varieties in time Waagen termed *mutations*. In 1891 Scott unearthed this distinction of Waagen's and clearly defined it as the hereditary or phylogenetic change of animals in time. Previous to this Osborn, without knowing of Waagen's statement, had discussed the same facts of the birth of new characters, describing them as 'definite variations.' Cope, it happens, did not follow this line of thought at all; but many other paleontologists did, notably Hyatt, whose peculiar style and multiplicity of terms obscured his depth of thought and extent of observation. Thus the term *mutation* acquired a definite significance among paleontologists.

It happened that De Vries, the eminent Dutch botanist, reading Scott's paper, mistakenly identified these new characters succeeding each other in time with those which he was observing as occurring contemporaneously in plants, and he adopted Waagen's term for the 'mutation theory,' which he has so brilliantly set forth, of the sudden production of new and stable varieties, from which nature proceeds to select those which are fit.

If paleontologists are correct in their observation, mutations may be figured graphically as an inclined plane, whereas De Vries's phenomena in plants represent a series of steps more or less extensive. Scott expressly excluded the element of discontinuity; and I believe there is no ground whatever for the assertion that the phenomena first named mutations by Waagen and independently observed by many paleontologists, are identical with the phenomena observed by De Vries in plants.

On the contrary, De Vries's facts accord with the favorite hypothesis of St. Hilaire. They demonstrate the law of *saltation*. This is the inevitable interpretation of the expositions of De Vries himself, of Hubrecht, and of the more recent references of Bateson in his British Association address. That saltation is a constant phenomenon in nature, a *vera causa* of evolution, no one can longer deny. Bateson shows that it harmonizes with Mendel's conceptions of heredity, and it may be regarded as *par excellence* the contribution of the experimental method.

Similarly, I regard mutation as a quite distinct phenomenon, and as *par excellence* the contribution of the paleontological method; it is the gradual rise of new adaptive characters neither by the selection of accidental variations nor by saltation, but by origin in an obscure and almost invisible form, followed by direct increase and development in successive generations until a stage of actual usefulness is reached, where perhaps selection may begin to operate. While clearly setting forth the difficulties, I at one time attributed definite variation or mutation to Lamarck's principle of the inherited effects of habit as the

only assignable cause; subsequently I realized that it was not explainable by the Lamarckian hypothesis.

I then attributed it to an unknown law of evolution, and there I believe it rests to-day, namely: as a process of which we do not know the cause. Still more recently, however, comes the discovery that original kinship is partly at least a control-principle. For example, in the descent of independent stocks of hornless animals arising from a common stock, rudimentary horn cores are found to appear independently in exactly the same region of the skull, indicating a kind of predetermination in the stock, or potential of similar evolution. The facts on which this law of mutation, properly called, rests have been misunderstood, totally denied, or explained away by selectionists as survivals of favorable out of indiscriminate variations. Even my colleague, Scott, has identified these phenomena with the saltations of De Vries. Nevertheless, I regard the genesis of new adaptive characters from almost imperceptible beginnings as a *vera causa,* and as one of the greatest problems we have to solve.

That a natural solution will be found goes without saying, although this principle, as stated, is undoubtedly of a teleological nature. Its philosophical bearings are of far reaching importance. Just as we demand a continent to transfer land animals from Australia to South America, so we demand a natural law to explain these facts.

The creative factors of fitness cooperating with selection, which, in my judgment, are now well demonstrated, reside either primarily in the environment, in the bodies of animals, or in the germinal cells—they all ultimately find their way into the germinal cells. They may be summarized as follows:

1. *Segregation.*—Besides the familiar geographical segregation of animals, which reaches its highest expression in insular forms, such as the pygmy fossil elephants of Malta and those recently discovered in Cyprus (Wade), there is the no less effective *segregation of habit* among animals existing in the same geographical regions and under the same climatic conditions, but seeking different varieties of food on different kinds of soil. These give rise to what I have called local adaptive radiations, a principle which explains the occurrence in the same country, and almost side by side, of very conservative as well as very progressive forms.

2. *Adaptive Modification.*—This is a plastic principle which tends in the course of life to an increasing fitness of the bodies of individuals to their special environments and habits, well illustrated among men in the influence of various trades and occupations and operating both in active and in passive structures. Consistent with the adaptive modification principle is the fact that every individual requires habit and environment to model it into its parental form; and in every change of environment or habit every individual is carried an infinitesimal

degree beyond the parental form; the wonderful phenomena of correlated development which puzzled Spencer so much are chiefly attributable to this principle.

These adaptive modifications are not directly inherited, as Lamarck supposed, but acting through long periods of time there results the *organic selection* (Morgan, Baldwin, Osborn), of those individuals in which hereditary predisposition happens most closely to coincide with adaptive modification, and there thus finally comes about an apparent, but not real, inheritance of acquired characters, as Lamarck, Spencer and Cope supposed.

3. *Variations of Degree.*—We should by no means exclude as true causes of evolution associated with both the above factors, the selection of those variations of degree or around a mean which conform to Quetelet's curve, the subject of the chief investigations of the Galton school, of Pearson and of Weldon, and which form the strongest remaining ground for Darwin's theory of selection in connection with fortuitous variation. For example, I regard the appearance of long-necked giraffes, of slender-limbed ruminants and horses, of long-snouted aquatic vertebrates, as instances of the selection of variations around a mean rather than of the selection of saltations. The selection of such variations where they happen to be adaptive has been an incessant cause of evolution.

4. *Saltation.*—Although Geoffroy St. Hilaire argued for paleontological evolution by saltation, I do not think we have much evidence in paleontology for the saltation theory. In the nature of the case, we can not expect to recognize such evidence even where it may exist, because wherever a new form appears or a new character arises, as it were, suddenly, we must suspect that this appearance is due to absence of the connecting transitional links to an older form. The whole tendency of paleontological discovery is to resolve what are apparently saltations or discontinuities into processes of continuous change. This, however, by no means precludes saltation from being a *vera causa* in past time, as rising from 'unknown' causes in the germ cells and as forming the materials from which nature may select the saltations which are adaptive from those which are inadaptive. The paleontologist has every reason to believe that he finds saltations in the sudden variations in the number of vertebræ of the neck, of the back, of the sacral region, for example. In the many familiar cases of the abbreviation or elongation of the vertebral column in adaptation to certain habits, a vertebra in the middle of a series can not dwindle out of existence, it must suddenly drop out or suddenly appear.

5. *Mutation.*—These new characters are also germinal in origin, because they appear in the teeth, which are structures fully formed beneath the surface before they pierce the gum, and therefore not subsequently modeled by adaptive modification, as the bones, muscles and

all the other tissues of the body are. Mutations are found arising according to partly known influences of kinship. They do not, so far as we observe, possess adaptive value when they first appear, but then frequently, if not always, develop into a stage of usefulness.

Fitness is, therefore, the central thought of modern paleontology in its most comprehensive sense, as embracing fitness in the very remote past, in its evolution toward the present and in its tendencies for the future. Just as the uniformitarian method of Lyell transformed geology, so the uniformitarian method is penetrating paleontology and making observations of animal and plant life as it is to-day the basis of the understanding of animal and plant life as it was from the beginning. Here again paleontology is not merely an auxiliary to zoology; it is chief of a division and enjoys certain unique advantages. We pass in review with the pedigrees and the prodigies of fitness, the entirely unreasonable, irrational, paradoxical extremes of structure, such, for example, as the pterosaurs, which far surpass in boldness and ingenuity of design any of the creations of the modern yacht builder which are mistakenly regarded by some as having reached an absurd extreme.

Problem of Historical Study.

The paleontologist must also be a historian; he has to deal with lineage, with ancestors, he comes directly upon the problem of kinship or relationship, and he has to determine the various means of distinguishing the true from the apparent relationships. It happens that fitness, while fascinating in itself, has led even the most faithful and skilful into the most devious paths away from the truth. The explanation of this apparent contradiction is in this wise. The ingenuity of nature in adapting animals is astounding, but it is not infinite; the same devices are resorted to repeatedly to accomplish the same purposes. In the evolution of long-snouted rapacious swimming forms, for example, we have already discovered that nature has repeated herself twenty-four times in employing the same processes to accomplish the same ends in entirely different families of animals.

This introduces us to one of the two great ideas which we must employ in the interpretation of facts, namely, the *idea of analogy*. We see far more clearly than Huxley did the force of this idea. Owen, Cope, Scott, Fraas and many others, under the terms 'parallelism,' 'convergence,' 'homoplasy,' have developed the force of the old Aristotelian notion that analogy is a similarity of habit, and that in the course of evolution a similarity of habit finally results in a close or exact similarity of structure; this similarity of structure is mistaken as an evidence of kinship. Analogous evolution does not stop in its far reaching consequences with analogies in organs; it moulds animals as a whole into similar form, as, for example, the ichthyosaurs, sharks

and dolphins; still more it moulds similar and larger groups of animals into similar lines or radii of specialization. Thus we reach the grand idea of analogy as operating in the divergencies or adaptive radiations of groups, according to which great orders of animals tend in their families and suborders to minic other orders, and the faunæ or collective orders of continents to mimic the faunæ of other continents.

Amid this repetition on a grand scale of similar adaptations, which is altogether comparable to what we know as having occurred over and over again in human history, the paleontologist as a historian must keep constantly before him the second great *idea of homogeny,* of real ancestral kinship, of direct blood descent and hereditary relationship. The shark and the ichthyosaur superficially look alike, but their germ cells are radically different, their external resemblances are a mere veneer of adaptation so deceptive, however, that it may be a matter of half a century before we recognize the wolf beneath the clothing of the sheep, or the ass in the lion's skin.

These two great ideas of analogy or similarity of habit, and homogeny or similarity of descent, do not run on the same lines; they are the woof and the warp of animal history. Analogy corresponds to the woof or horizontal strands which tie animals together by their superficial resemblances in the present, homogenies are the warp, or the fundamental vertical strands which connect animals with their ancestors and their successors. The far reaching extent of analogous evolution was only dimly perceived by Huxley, and constituted his one great defect as a philosophical anatomist. Its power of transforming unlike and unrelated animals has accomplished miracles in the way of producing a likeness so exact that the inference of kinship is almost irresistible.

The paleontologist who would succeed as historian must first, therefore, render himself immune to the misguiding influences of analogy by taking certain further precautions which will now be explained by watching his procedure as historian.

Paleontology as the history of life takes its place in the background of recorded history and archeology, and simply from the standpoint of the human pedigree is of transcendent interest. Although it has progressed far beyond the dreams of Darwin and Huxley, the first general statement which must be made is that the actual points of contact between the grand divisions of the animal and plant kingdom, as well as between the lesser and even many of the minor divisions, have yet to be discovered. You recall that the older grand divisions of the Vertebrata, to which we must confine our attention, were suggested by the so-called Ages of Fishes, of Amphibians, of Reptiles and of Mammals. Even within these grand divisions we observe a succession of more or less closely analogous groups. Each of these groups has its

more or less central starting point in a smaller and older group which contains a large number of primitive or generalized characters.

The search for the primitive central form is always made by the same method of reasoning, a method which was first clearly outlined by Huxley, namely, by the more or less ideal reconstruction of the primitive central form from which radiation has occurred. This is a very difficult matter where the primitive central form is not preserved either living or as a fossil. In such instances we may by analysis of all the existing forms prophesy the structure of the primitive central form, as Huxley, Kowalevsky and Cope did in the case of the hoofed animals, a prophecy which was nearly fulfilled by the discovery in northern Wyoming of *Phenacodus*. In other more fortunate cases the primitive central form survives both living and fossil, as in the remarkable instance of *Paleohatteria* of the Permian and the Tuatera lizard (*Hatteria*) of New Zealand, which gave rise to the grand adaptive radiation of the lizards, mosasaurs, dinosaurs, crocodiles, phytosaurs and probably of the ichthyosaurs.

In the reconstruction of these primitive central forms, we must naturally discriminate between analogy and homogeny, and paleontologists are not agreed in all cases on such discrimination. On the border region, in fact, where the primitive central forms are still unknown, where analogy has reached its most perfect climaxes and imitations, are found the great paleontological controversies of to-day. For example, among the paleozoic fishes, the armored ostracoderms (*Pteraspis, Cephalaspis, Pterichthys*) and the arthognaths (*Coccosteus, Dinichthys*) by some authors (Hay, Regan, Jaekel) are placed in the single group of placoderms, while by other authors (Smith Woodward and Dean) they are regarded as entirely independent and superficially analogous groups. The dipnoi or lung fishes (*Ceratodus, Protopterus*) present so many analogies with the Amphibians (salamanders and frogs) that they were long regarded as ancestors of the latter; but more searching anatomical and paleontological analyses and recent embryological discoveries have proved that the dipnoi and amphibia are parallel analogous groups descended alike from the crossopterygian fishes, fishes which are now represented only by the bichir (*Polypterus*) of Africa. It is interesting to recall parenthetically that two naturalists, Harrington, an American, and Budgett, an Englishman, have given their lives to the solution of this problem in searching for the embryology of *Polypterus*. The latter explorer only was successful.

Missing Links between the Great Classes of Vertebrates.

Among the varied fins of the crossopterygians we have nearly, but not actually, discovered the prototype of the hand and the foot, the fingers and toes of the primordial amphibian. Volumes upon volumes

have been written by embryologists and comparative anatomists on the hypothetical transformation of the fin into the hand. Considering the supreme value of the hand and foot in vertebrate history, this was certainly the most momentous transformation of all and worthy of volumes of speculation; but as a matter of fact, the speculation has been a total failure, and this problem of problems will only be settled by the future discovery in Devonian rocks of the actual connecting link, which will be a partly air-breathing fish, capable of emerging upon land, in which the cartilages of the fin will be found disposed very much as in the limbs of the earliest Carboniferous amphibians. The unity of composition in the hand and the foot points to an original similarity of habit in the use of these organs.

This missing point of contact, or of the actual link between amphibians and fishes, is equally characteristic of paleontology as history from the top to the bottom of the animal scale. We are positive that Amphibians descended from fishes, probably of the crossopterygian kind, but the link still eludes us; we have brought the reptiles within close reach of the amphibians, but the direct link is still to be found; mammals are in close proximity to a certain order of reptiles, but the connecting form is still undiscovered; man himself is not far from the various types of anthropoid apes, but his actual connecting relationship is unknown.

We are no longer content, however, with these approaches to actual contact and genetic kinship, we have toiled so long both by discovery and by the elimination of one error after another, and are so near the promised land, we can hardly restrain our impatience. I venture to predict that the contact of the Amphibia with the fishes will be found either in America or Europe. No such prediction could be safely made regarding the connecting form between the amphibians and reptiles, because America, Eurasia and Africa all show in contemporaneous deposits evidence that such connection may be discovered at any time. The transformation from reptiles to birds will probably be found in the Permian of America or Eurasia; chances of connecting the mammals with the reptiles are decidedly brightest in South Africa; while in Europe, or more probably in Asia, we shall connect man with generalized catarhine primates.

Passing from these larger questions of the relations of the great classes of vertebrates to each other, let us review the problems arising in the individual evolution of the classes themselves.

Geographical Problems.

The primordial, solid-skulled or stegocephalian amphibia of the Permian diverged into a great variety of forms which wandered over Eurasia and North America so freely that, for example, we find as close a resemblance between certain Würtemberg and New Mexican genera

(*Metopias*) as between the existing stag of Europe and the wapiti deer. Which branch of these primordial amphibians gave rise to the modern frogs and salamanders we do not know. This and hundreds of similar facts suggest the vital importance of paleogeography.

As regards paleogeography, the great induction can be made that, throughout the whole period of vertebrate evolution and until comparatively recent times, Europe, Asia and North America constituted one continent and one life region, or Arctogæa (Huxley 1868, Blanford 1890), with which the continents of the southern hemisphere, namely, Africa, South America and Australia, were intermittently, but not continuously connected by land. A great southerly continent, Notogæa (Huxley 1868), connected with a south polar Antarctica, now submerged, is a theory very widely supported by zoologists and, I believe, by botanists, although its existence is still denied by certain geographers (Murray). We find Permian, Jurassic, late Cretaceous and early Tertiary proofs of Antarctica in the fresh-water crustaceans (Ortmann), in fresh-water fishes (Gill), in littoral mollusca (Ortmann), in reptiles (Smith Woodward and Osborn), in birds (Forbes and Milne Edwards), in worms (Beddard), in the Australian animals (Spencer), in the fossil mollusca of Patagonia (Ortmann) and in the fossil mammals of Patagonia (Ameghino). To marshal and critically examine all this evidence and convert this most convenient Antarctic hypothesis into an established working theory I consider one of the most pressing problems of the day.

Problem of the Source of the Reptiles and Mammals.

Returning from this geographical détour to paleontology as history, we should first note that already in the Permian there was developed such an astonishing variety and differentiation of the reptiles that we must look to future discoveries in the Carboniferous to find the actual points of descent of reptiles from the amphibia. These Permian and Lower Triassic reptiles are of three kinds, comparable to a parent (Cotylosauria) and two offspring (Anomodontia and Diaptosauria). In the parent group (the Cotylosauria, or solid-skulled reptiles,) we find so many fundamental similarities to the Stegocephalia, or solid-skulled amphibia, that only by the possession of many parts of the body can we surely ditinguish reptile from amphibian remains. The primordial reptile was probably altogether a land animal continuously using its limbs in awkward progression, bringing forth its young by land-laid eggs and probably possessing gills only as vestiges. These cotylosaurs show very wide geographical distribution, South Africa, Siberia, Great Britain and North America, and equally remarkable adaptive radiations of habit into small and large, horned and hornless types, some of which were certainly dying out branches, while others led into the two offspring groups.

Leaving this parental order, in the Permian and Lower Trias, we first see in the older offspring, the Anomodontia, reptiles of varied size and description, carnivorous and herbivorous in habit, most abundantly found in South Africa, in Asia and in Europe, and not at all as yet in America, either North or South. The high degree of fitness for different habits, or radiation, of the Anomodonts is distinguished from that of any other reptiles at any time by its numerous analogies to the radiation of the mammals, namely, into very large and very small forms, into carnivorous and herbivorous, into terrestrial and possibly into aquatic types; in fact, some of these animals, if seen on land to-day might readily be mistaken for mammals.

The second offspring of the Cotylosauria, on the contrary, the Diaptosauria, are essentially and unmistakably saurians; that is, if seen about us to-day they would undoubtedly at first be described as lizards. They were still more broadly cosmopolitan in range, being scattered over both Americas (Pelycosauria, Proganosauria), Europe (Protorosauria, Rhynchosauria), Asia (Rhynchosauria) and Africa (Proganosauria, Rhynchosauria). They are also found highly diversified in type, but all their analogies of fitness are with the reptiles and not with the mammals. It is of prime importance that more of these diaptosaurs be found, and that those already known in the museums should be more critically examined. What we already know, however, enables us to establish the following facts: first, that the parentage of these animals is more probably among the cotylosaurs than among the anomodonts, and second that already in the Permian they had formed a sufficiently large number of branches to be regarded as a fully evolved radiation.

Problem of the Adaptation of the Mesozoic Reptiles.

In the Triassic the offspring of the anomodonts and of the diaptosaurs appear as the third generation from the cotylosaurs.

The recurrent difficulty arises that the actual points of contact or transition from the anomodonts are wanting, and we must continue to reason by the ideal reconstruction of the hypothetical linking forms. Such reasoning connects the Testudinata (turtles and tortoises), the Sauropterygia, or marine plesiosaurs, and, singularly enough, our own ancestors, the primordial mammals, with the group of anomodonts and not at all with that of the diaptosaurs. Here in the Upper Permian and Lower Trias we must await both discovery and the closest critical analysis, but if this still hypothetical affiliation be confirmed by discovery, as I personally am sanguine it will be, then it will be true to say that the mammals, and hence man, are much more nearly affiliated to the anomodonts than to either the lizards or snakes, which are both on the great Diaptosaur branch. Our presence on the great Anomodont branch and remoteness from the creeping and crawling

reptiles will perhaps afford some consolation to those who still shrink from the ultimate consequences of Darwin's 'Descent of Man.' As regards degrees of probability, it must be said that while the affiliation of the Plesiosaurs and Testudinata with the Anomodont group still requires confirmation, the connection of the mammals with certain Anomodonts (Theriodontia) is not only probable but is almost on the verge of actual demonstration, and at present it seems likely that the Karoo Desert of South Africa will enjoy the honor of yielding the final answer to the problem of the *origin of mammals,* which has has stirred comparative anatomists for the last sixty years.

Turning to the progeny of the other branch, the Permian diaptosaurs, we find them embracing (with the exception of the Testudinata and plesiosaurs) not only vast reptilian armies, marshaling into thirteen orders, mastering the distinctive Age of Reptiles (Triassic, Jurassic and Cretaceous), and surviving in the four existing orders of lizards, snakes, crocodiles and tuateras, but we also find them giving off the birds as their most aristocratic descendants. The bold conception of the connection between these thirteen highly diversified orders and a simple ancestral form of diaptosaur, typified by the Permian *Palæohatteria* or the surviving *Hatteria* (tuatera of New Zealand) we owe chiefly to the genius of Baur, a Bavarian by birth, an American by adoption. Absolutely diverse as these modern and extinct orders are, whatever material for analysis we adopt, whether paleontological, anatomical or embryological, the result is always the same—the reconstructed primordial central form is always the little diaptosaurian lizard. The actual lines of connection, however, are still to be traced into the great radiations of the Mesozoic.

The chief impression derived from the survey of this second branch of the Reptiles in the Mesozoic as a whole is again of radiations and subradiations from central forms and the frequent independent evolution of analogous types. The aquatic life had been already chosen by the plesiosaurs and by some of the turtles, as well as by members of three diaptosaur orders (Proganosauria, Choristodera, certain Rhynchocephalia), two of which were surviving in Jurassic times. Yet it is independently again chosen by four distinct Triassic orders, always beginning with a fresh-water phase (Parasuchia, Crocodilia), and sometimes terminating in a high sea phase (Ichthyosauria, Mosasauria, Crocodilia). In the Jurassic period there were altogether no less than six orders of reptiles which had independently abandoned terrestrial life and acquired more or less perfect adaptation to aquatic life. Nature, limited in her resources of outfitting for aquatic life, fashioned so many of these animals into like form, it is small wonder that only within the last two years have we finally distinguished all the similarities of analogous habit from the similarities of real kinship.

The most conservative members of this second branch are the

terrestrial, four-footed, persistently saurian or lizard-like forms, the tuateras and the true lizards; but from these types again there radiated off one of the marine orders (Mosasauria), the limbless snakes (Ophidia), while the lizards themselves have in recent times diverged almost to the point of true ordinal separation.

The most highly specialized members of this second branch are of course the flying pterosaurs, of whose ancestry we know nothing. Also in a grand division by themselves there evolved the dinosaurs, distinctively terrestrial, ambulatory, originally carnivorous, and probably more or less bipedal animals. Not far from the stem of the dinosaurs was also the source of the birds, also distinguished by bipedalism.

The working plan of creation becomes day by day more clear; it is, that each group, given time and space, will not only be fruitful and multiply, but will diversify in the search for every form of food by every possible method. Specialization in the long run proves fatal; the most specialized branches die out; the members of the least specialized branches become the centers or stem forms of new radiations.

The Mammals of Four Continents.

So it is among the mammals, in which these principles find new and beautiful illustrations, although our knowledge of the early phases is fragmentary in the extreme. Our sole light on the first phase, in fact, is that obtained from the two surviving monotremes of the Australian region; from this extremely reptilian and egg-laying monotreme phase it appears, although opinion is divided on this point, that before the Jurassic period (*i. e.*, already in the Trias) two branches were given off, the placental, from which sprang all the modernized mammals and the marsupial.

The marsupials appear to have passed through an arboreal or tree life condition, something similar to that seen in the modern opossum. The marsupials found their opportunity for unchecked adaptive radiation in Australia and despite the disadvantage of starting from a specialized arboreal type (Huxley, Dollo, Bensley), through the later Cretaceous and entire Tertiary a richly diversified fauna evolves, partly imitating the placentals and partly inventing entirely new and very peculiar forms of mammals, such as the kangaroo.

The oldest placental radiation which is fully known is that which was first perceived in Europe and fully recognized by the discovery in 1880 of the basal Eocene mammals of North America—it may be called the Cretaceous radiation. These mammals are distinctly antique, small-brained, clumsily built, diversified, imitative both of the marsupial and of the subsequent placental radiations; and our fuller knowledge of them after twenty-five years of research is at once satisfying and disappointing, satisfying because it gives us prototypes of the higher or modern mammals, disappointing because few if any of

these prototypes connect with the modern mammals. This fauna is found in the Cretaceous and basal Eocene of Europe, North America, and possibly in Patagonian beds of South America (Ameghino), and while giving rise to many dying-out branches, by theory furnished the original spring from which the great radiations of modern mammals flowed. But practically again we await the direct connections and the removal of many difficulties in this theory. In fact, one of the great problems of the present day is to ascertain whether this radiation of Cretaceous mammals actually furnished the stock from which the modern mammals sprang, or whether there was also some other generalized source.

The Tertiary, or Age of Mammals, presents the picture of the dying out of these Cretaceous mammals in competition with the direct ancestors of the modern mammals. I use the word modern advisedly, because even the small horses, tapirs, rhinoceroses, wolves, foxes and other mammals of the early Tertiary are essentially modern in brain development and in the mechanics of the skeleton as compared with the small brained, ill-formed and awkward Cretaceous mammals.

Whatever the origin, two great facts have been established: *first,* the modern mammals suddenly appear in the Lower Eocene (as distinguished from the basal Eocene, in which the Cretaceous mammals are found), and *second,* they enjoy a more or less independent evolution and radiation on each of the four great continents. There thus arose the four peculiar or indigenous continental faunæ of South America, of North America, of Europe and Asia or Eurasia and of Africa. Of these South America was by far the most isolated and unique in its animal life. North America and Eurasia were much the closest, and Africa acquired a half way position between isolation and companionship with Eurasia.

South America.—The most surprising result of recent discovery is that the foreign element mingled with the early indigenous South American fauna is not at all North American but Australian. The wonderful variety of eight orders of indigenous rodents, hoofed animals, edentates and other herbivores were preyed upon by carnivores of the marsupial radiation from Australia, which apparently came overland by way of Antarctica. There are possibly here also some South African foreigners. The South American radiation more or less closely imitated that of the northern hemisphere. Late in Tertiary times North America exchanged its animal products with South America, practically to the elimination of the latter.

Eurasia and North America.—Each of these continents contained four orders of mammals in common with South America, namely, the Primates (monkeys), the Insectivores (moles and shrews), the Rodents (porcupines, mice, etc.), and the Edentates (armadillos, etc.). From some early Tertiary source North America, Eurasia and Africa also acquired in common four great orders of mammals which are not found

at all in the indigenous fauna of South America. These are the Carnivores (dogs, cats, etc.), the Artiodactyls (deer, bovines, camels, and pigs), the Perissodactyla (horses, rhinoceroses and tapirs), and the Cheiroptera (bats). Migration and animal intercommunication between North America and Eurasia was very frequent. The history of these nine orders of mammals in North America and Eurasia developed as follows: Certain families indigenous to North America both evolved and remained here, others finally migrated into Europe and South America. Similarly Eurasia had its continuous evolution into forms which remained at home as well as into those which finally migrated into North America and even into South America.

Africa.—The most astonishing and gratifying features of recent paleontological progress has been the revelation of what was taking place in Africa at the same time (Andrews and Beadnell). This discovery came with its quota of unthought of forms, also with the representative of three orders which it had been prophesied would be found there, namely, the Proboscidea (elephants and mastodons), the Sirenia (manatees and dugongs), and the Hyracoidea (conies). The basis of this prophecy was the anomalous fact that these animals suddenly appeared in Europe in the Miocene and Pliocene fully formed and without any ancestral bearings; it was certain that they had evolved somewhere, and Africa seemed the most probable home, rather than the currently accepted unknown regions of Asia. Thus by a sudden bound paleontology gains the early Tertiary pedigree of the elephants and of two if not three other orders.

Africa in the early Tertiary, whether from the absence of land connections or from climatic barriers, was a very independent zoological region. Some predatory Cretaceous mammals (Creodonta or primitive Carnivores) found their way in there, also certain peculiar artiodactyls (Hyopotamids). Here also were two remarkable types of mammals (*Arsinoitherium, Barytherium*) which have no known affinities elsewhere, as well as the extremely aberrant Cetaceans or Zeuglodonts.

The Outlook.

From all these continents we have, therefore, finally gathered the main history during the Tertiary period of eighteen orders of mammals. We have still to solve the origin of the cetaceans or whales, still to connect many of these orders which we call 'modern' with their sources in the basal Eocene and Upper Cretaceous, still to follow the routes of travel which they took from continent to continent. Encouraged by the prodigious progress of the past twenty-five years, we are confident that twenty-five years more will see all the present problems of history solved, and judging by past experience we may look for the addition of as many new and no less important ones.

SOCIAL AND POLITICAL EFFECTS OF IMMIGRATION.

By Dr. ALLAN McLAUGHLIN,

U. S. PUBLIC HEALTH AND MARINE HOSPITAL SERVICE, WASHINGTON, D. C.

THE assimilation of hundreds of thousands of aliens every year undoubtedly produces social and political effects worthy of close study, which are overlooked by some and exaggerated by others.

The subject of the illiteracy of immigrants brings us naturally to the question of illiteracy at home, and statistics show many remarkable things in this connection. The illiteracy of the United States as a whole is something over eleven per cent., while the percentage of illiteracy among immigrants from England, Ireland, Scotland, Wales, Norway, Sweden, Denmark, Finland, France or Germany is 4 per cent. or less.

Another fact demonstrated by statistics is that in the states which receive a great proportion of aliens every year, the percentage of illiteracy is low, while in the states where the percentage of foreigners is lowest, as in Georgia, Tennessee and Kentucky, the percentage of illiteracy for the state is very high.

The question of illiteracy in our own country is largely a question of presence or absence of schools, and statistics show that the immigrants go to the states which have the best common school system and are thus best fitted to reduce their illiteracy. The fact that illiteracy in New York, Pennsylvania, Illinois and Massachusetts has decreased in spite of the thousands of aliens received every year, speaks well not only for the public school system of these states, but also for the adaptability of the immigrant and his desire for education.

Thus it will be seen from the tables given below that, although illiteracy is high among the foreign born in cities as compared with native whites, the native white children of foreign born parents compare favorably with children of the native white. In regard to percentage of illiteracy and school attendance, Table I. shows that the illiteracy of the foreign born is reduced in one generation, as shown by the native children of foreign parents, from 12.9 per cent. to 1.6 per cent. It also shows that the native children of foreign parents have a much lower percentage of illiteracy than the native whites of native parentage.

Table II. shows that a greater percentage of native white children of foreign parentage attend school between the ages of five and fourteen, than of native whites of native parentage. Table III. shows that

native whites of foreign parentage attend more steadily and persistently than native whites of native parentage, and in this regard the foreign born children lead both the other classes.

TABLE I.

Nativity and Parentage.	Percentage of Illiteracy.	
	1890.	1900.
Native white of foreign parents	2.2	1.6
Native white of native parents	6.2	5.7
Foreign white	13.1	12.9
Total white	7.7	6.2

TABLE II.

Nativity.	Age.	
	5 to 9 Years.	10 to 14 Years.
Native white of foreign parents	59.1 per cent.	86.2 per cent.
Native white of native parents	48.6 " "	83.8 " "
Foreign white	58.2 " "	73.0 " "

TABLE III.

Nativity and Parentage.	Percentage of School Children Attending School Six Months or More in Each Year.	
	Males.	Females.
Native white of foreign parents	88.7	90.6
Native white of native parents	68.7	71.4
Foreign white	89.1	90.8

Illiteracy is seldom a matter of choice with the peasant. It is usually a matter of bad government. The governments of certain countries maintain no free school system, and paid schools of academies are out of the reach of the miserable peasants.

In other countries the government places monetary or religious restrictions upon certain races which prevent their attendance at school. One often hears the query, 'What is the effect of a mass of illiterate foreigners upon society?' There is very little effect. The illiterate foreigners in our own large cities are ostracized socially, as strictly as the negro in the south. 'These foreigners do not assimilate' is heard every day. How can they? They can not take the initiative. The Italian, or the Jew, or the Slav, do not shrink away from their American neighbors more than their American neighbors shrink from them.

This mutual aloofness will persist through one or two generations. No sane man expects the Americanization of any but English-speaking immigrants in the first generation, but there is hope, and bright hope, for the immigrants' American bred children, even if their parents be

illiterate. It is also necessary to discriminate between the man who is illiterate and the man who is uneducated. A man may be unable to read or write, and yet he may be able to mine coal, or set out grape cuttings, and trim and train the vines. This man is illiterate, but he can not be called uneducated. His illiteracy may be due to causes over which he had no control, as persecution of, or discrimination against, his race by the government under which he lived. The races which have suffered most show a high percentage of illiteracy—the Pole, the Lithuanian, and the Jew. Within seventy-five years of catholic emancipation in Ireland, and the revocation of the penal laws, illiteracy among Irish immigrants dropped from above 50 per cent. to 4 per cent. Other races have as great a hunger for education as these Irish, and meet their first opportunity for sending their children to school, after arriving in America.

Many an Irish immigrant of fifty years ago, who could neither read nor write, and who perhaps could only fix the date of his birth by its proximity to 'the night of the big wind,' became prosperous here, sent his children to school and lived long enough to see them occupy high places in the land of his adoption.

The Americanization of immigrants who do not speak English will take a longer time than was necessary for the Americanization of immigrants from Ireland, but time and American schools work wonders, and already the children of poor Russian Jews of the Ghetto can be pointed out as making their mark in the business or professional world.

The majority of the immigrants who are illiterate come here to supply the demand for unskilled labor, and the mere fact of being able to read or write in their own language would not aid them one iota in their work or make them one whit more desirable to their employers. There is often expressed a fear of the growing numbers of the illiterate laborers in this country, because of their tendency to socialism or anarchy. As a matter of fact the illiterate laborer is less dangerous from this cause than the discontented laborer of some education. The illiterate immigrant can only be reached from the public platform and the anarchistic exhorter can be easily suppressed or deported, but it is not so easy to prevent the dissemination of anarchistic pamphlets, which sow the seeds of discord and fan the flame of discontent in the heart of the laborer who can read.

Much has been written of the great proportion of criminals and paupers which is made up of aliens. In accepting statements of this character, it is well to take into consideration the fact that position in life has much to do with the tendency to commit crime, and that our immigrants necessarily begin life at the lowest rung of the ladder. Paupers and criminals will ever come in the greatest proportion from

the tenement dwellers of our crowded cities. The unfortunates, regardless of race, who are exposed to the hardships of the tenement and temptations of the slum, may be expected to furnish the largest proportion of inmates for our penal and charitable institutions. Statistics comparing the tendency to pauperism and criminality of the foreign born with that of natives, are apt to be misleading. These statistics almost invariably fail to take account of the predominating influence of sex and age upon crime. It can be demonstrated that the vast majority of criminals are of the male sex and between the ages of 20 and 45 years. The males exceed the females among immigrants in the proportion of 2.5 to 1, and about 75 per cent. are between the ages of 15 to 40. Persons less than 15 seldom are criminals and the immense number of natives below that age contribute few to the number of criminals, but help greatly to reduce the criminal average in the total native population. The great majority of immigrants, on the other hand, are of the sex and age which predispose to crime. It is also a fact that before our laws were made strict, and rigidly enforced, thousands of paupers, cripples and criminals were shipped here from Europe, and the effect of these upon our institutional statistics can be imagined, but should not be charged to the immigrant of to-day.

Even if the immigrant could be eliminated from our social problem, Utopia would not be with us. The lowly place now occupied by the foreign born, the lowest stratum of our social formation, would still exist, and would then be made up of urban degenerates or native failures from the rural districts. Idealists seem to think that the immigrant is wholly responsible for the slum with its crime and pauperism. The responsibility for the slum can be divided between money-grasping property owners and an indifferent puerile civic administration. The immigrant finds the tenements and the slums already established when he arrives and is the victim and not the cause of them.

The tendency of foreign-born towards cities, as places of permanent residence, is a well-known and widely discussed social problem. The real distribution of our immigrants is merely indicated by the destination given by newly-arrived aliens at Ellis Island, and the more accurate knowledge of their places of residence here is given by the United States census returns. Immigrants at Ellis Island may give New York as their destination, yet after a short time go to Wisconsin, Texas or Louisiana. Others destined for the far west may never proceed farther than the Atlantic seaboard, but the United States census finds them in their permanent homes, wherever they may be, from Maine to California, from Alaska to Florida. This tendency of the foreign born to crowd our large cities is not of recent development. It has been the case ever since our cities attained great size. The

percentage of foreign born in our country is not greater than it was thirty or forty years ago; in fact it can be said to be decreasing, as shown in the following tables:

Year.	Total Foreign Population.	Per cent. of Foreign Population.
1860	4,136,175	15.04
1870	5,567,229	14.44
1880	6,679,943	13.32
1890	9,249,547	14.77
1900	10,341,246	13.6

Inclination for city life is not confined to any particular race, nor to the alien alone. All races contribute to our crowded cities, some of course more constantly than others, but the best and the worst are alike fully represented. The congestion in the cities is increased also by our own native born rural population, which furnishes an ever-increasing quota to the army of city dwellers.

The great number of foreign born inmates of insane asylums throughout the country indicates that in the past too little restriction was placed on the mentally defective, and that the opportunity afforded by an inspection at the port of entrance was too scanty to be of much value. A man mentally oblique or subject to periods of insanity would, without doubt, pass the inspectors at the port of landing, if he was at that time rational and quiet. Epileptics, too, had an excellent chance of being admitted, their rejection depending on the remote possibility of their having a paroxysm while passing the inspectors. An anarchist in passing the officers would of course be docile and quiet, and his detection extremely difficult.

Mr. Goodwin Brown, attorney for the New York State Commission of Lunacy, stated before the Senate Committee on Immigration, Washington, 1902, that although only 25 per cent. of the population of the state of New York were foreign born, 50 per cent. of the inmates of the State Insane Asylum were foreigners. He also stated that this excess is not alone exhibited in New York statistics, but that an excess of 17 per cent. existed throughout the entire country of foreign born insane over the percentage of foreign born population. That these mentally defective persons were sent formerly in large numbers by persons living in Europe is scarcely open to question, but the period of government supervision of, and of power to deport, the landed alien, has been extended to two years (Act of 1903). Under this wise provision, an insane person of foreign birth, upon admission to an asylum, is investigated, and if landed within two years can be deported. The same clause covers the deportation of idiots and epileptics, so that we are now much better protected against these burdens than ever before. An additional protection is given by that part of Section 2, Law of

1903, which places in the excluded classes 'persons who have been insane within five years previous, and persons who have had two or more attacks of insanity at any time previously.'

Immigrants established years ago a reputation for bringing in epidemic diseases. They have played their part in the past in outbreaks of typhus, smallpox and cholera, but with the disappearance of the old immigrant sailing ships, the advent of the swift, clean ocean steamships and efficient modern methods of quarantine and prevention of disease, the immigrant to-day as a carrier of epidemic disease no longer causes us apprehension. The relation of the immigrant to the public health has already been discussed in an article in THE POPULAR SCIENCE MONTHLY, and it is only necesary here to refer to diseases peculiar to, or prevalent among immigrants, as one of the social effects of immigration. Of these, trachoma, a contagious form of granular lids, is one of the most obstinate and destructive diseases of the eye. Oculists from all parts of the country claim that this disease was introduced by immigrants and disseminated by them, from foci of the disease, established in their tenements.

The disease is now epidemic in the poorer districts of many of our cities, but since 1897 has been one of the causes for exclusion of aliens. About the same time favus, a loathsome contagious disease of the scalp, was made a cause for exclusion. Favus is a typical immigrant disease and can not spread among persons of cleanly habits.

These two diseases, favus and trachoma, constitute 97 per cent. of the total cases of loathsome or dangerous contagious disease found in arriving aliens. After they were classed as causes for exclusion they were responsible for more determined effort to evade our laws than had ever before been exhibited. Various means of escaping inspection were resorted to, the placing of diseased steerage aliens in the cabin (cabin passengers were not inspected until 1898), the use of false naturalization papers, entrance by way of Canada or Mexico, were all employed as modes of entrance. One by one, these gateways have been closed, and with the increasing vigilance of trained medical officers at our ports and upon the Canadian and Mexican frontiers, we shall be amply protected in the future from this menace.

The ill effects of immigration upon politics are all traceable to the evils of criminal or careless naturalization. These evils are most in evidence in the large cities, but a recent investigation by the attorney general of the United States, shows that the loose administration of the naturalization laws extends to the smaller cities and rural communities as well. President Roosevelt in his message to the Fifty-eighth Congress, December, 1903, forcibly presented the picture of fraudulent naturalization and its baneful effect upon the moral health of the body politic.

The federal grand jury, recently in session in New York in relation to the naturalization of aliens, adopted resolutions condemning the wholesale manufacture and sale of counterfeit and altered certificates of naturalization, and recommended new legislation to insure uniformity of practise in the various states, an engraved certificate and other precautions to prevent counterfeiting.

Mr. C. V. C. Van Deusen, special examiner in regard to naturalization, in his report to the attorney-general, November, 1903, says in part:

> The evidence is overwhelming that the general administration of the naturalization laws has been contemptuous, perfunctory, indifferent, lax and unintelligent, and in many cases, especially in inferior state courts, corrupt.
>
> I find that it is and has been for years past the practise of judges of state courts to hold evening sessions of court at the behest of political leaders for the sole purpose of naturalizing hundreds of aliens for political purposes with a full knowledge on the part of the judges that the aliens have been bribed to become citizens and voters by the payment of their naturalization fees by the political organizations.
>
> In those states in which the naturalization fee is not fixed by statute, or where the fees are retained by the judge or clerk, the 'naturalization business' of political organizations is a matter of competitive bidding by local courts and is awarded to the lowest bidders.
>
> In those states which prescribe by statute the naturalization fee, which must be accounted for by the clerk, it is the general practise of political organizations to select a specific court presided over by a judge of like political faith, to which the aliens, 'rounded up' by the district workers, are sent with official cards addressed to the clerk of the court requesting that final papers be issued to the bearer. These cards are afterwards redeemed by the political organization by the payment of the amount of the fees represented by them. In many cases clerks of courts demand advance payment of these fees from the political organization, having a due regard for the fact, based on previous experience, that it is often impossible to collect the money from the political committees after an election has passed.
>
> In many cases clerks of courts remit the naturalization fees in cases of aliens sent by their political organizations as their contributions to the campaign fund, while exacting the last cent permitted by law from aliens not 'indorsed' by such organization.
>
> In many instances the judge passing upon the qualifications of aliens for citizenship sent him by his political organization is a candidate for reelection, the result of the election being often decided by the vote of these aliens. Under these circumstances it is not strange to find that little or no attempt is made by such judge to ascertain the fitness of the alien for citizenship and that the number rejected is practically *nil*. It is a common thing for an alien rejected in one court to be admitted in another court on the same day. In one case I found that a judge had held an impromptu session of court late at night in a railroad station while waiting for a train for the purpose of conferring citizenship upon a number of aliens whose votes were needed at an election.
>
> In another case a judge entered an order revoking certificates of citizenship granted to seven aliens by him, under the impression that they had been sent by his political organization, but who were afterwards repudiated by that organiza-

tion. The order recited, as a reason for the revocation, the fact that the fees had not been paid.

In many instances I found that it was common knowledge that clerks of courts had issued, in the aggregate, hundreds of certificates of citizenship to aliens who never appeared in court, and afterwards forged the court records to make it appear that they had been admitted in open court.

Other clerks have furnished certificates blank as to names of aliens, but bearing the seal of the court and official signatures to members of his political organization, who have filled in the names of aliens, the clerk subsequently entering them in the court records as having been admitted in open court.

Mr. Van Deusen in summing up the situation makes the following statement and prediction: "These evils and frauds have existed for years, exist to-day, and will continue to exist and multiply until radical and stringent changes are made in the naturalization laws, and a strict supervision of their administration imposed."

It is unfair to charge to the alien the political corruption, and cheapening of the rights of citizenship, resulting from this condition of fraudulent or careless naturalization. The fault is in our laws, and to an even greater extent in the lax administration of them.

The attorney general, in his report for 1903, outlines a plan for legislation which would undoubtedly prove effective in eradicating these evils. He presents the following recommendations:

1. The omission from the statutes as they now stand of the question of intent and guilty knowledge where an offender has in his possession a fraudulent certificate of naturalization unlawfully obtained in any manner whatever, or where a fraudulent certificate so held and obtained is used for any purpose whatever. Such a change would permit prosecutions for the possession of a fraudulent certificate unlawfully obtained, or for the use of a fraudulent certificate irrespective of the intent of the oath of the applicant and witness on the certificate, which is to be regarded as presenting merely a question of fact.

2. That the law be amended so as to compel an alien at the time of applying for citizenship to present from the appropriate immigration authorities a certificate showing his age and the date of his arrival and containing also his physical description similar to that in a passport. This certificate should form a part of the court records, like his application for citizenship.

3. The petition and application and all certificates should be uniform throughout the United States, and the final certificate of citizenship issued by any court throughout the country should contain a physical description of the applicant and holder on the back thereof, for the purpose of identification and to avoid substitution.

4. The certificates should be printed in Washington under government direction, containing a watermark similar to United States obligations, and the unlawful possession of or counterfeiting of such certificates should be made an offense against the United States. The blank certificates should be distributed to the various courts on requisition, and each one should be properly numbered and recorded.

5. The power of issuing certificates of naturalization should be withdrawn by congress from the various state courts and should be restricted to United States courts.

6. All administrative matters relating to naturalization should be committed to one central government bureau.

7. It should be made a crime against the United States to sell or transfer declarations of intention, and it should be provided that after sufficient proof has been submitted to a court, establishing the fact that a certificate is fraudulent in any respect, said certificate shall be canceled of record.

These legislative suggestions of the attorney-general are as comprehensive as they are timely, and will probably be accepted by Congress as a basis for curative legislation. The card index system now employed by our immigration officials, for recording the name and date of arrival of each and every alien, could be elaborated so as to contain a physical description as well. This would prove valuable as a means of identification as outlined in the second suggestion of the attorney-general.

Economic Effects of Immigration.

The economic effects of immigration can not be accurately judged by the total number of immigrants landed each year at our ports. Hundreds of thousands go back to Europe each year, and a very large proportion of those traveling in the steerage to Europe are returning aliens. In spite of our immense total of yearly steerage arrivals, the percentage of foreign born in the United States is not increasing and is slightly less than it was ten years ago. Therefore in considering the effect of numbers, our judgment should be based upon census reports of the foreign born population. In regard to occupation and geographical distribution, we must also judge the alien after he is established here, rather than by the statement he makes to the immigration officials upon arrival. During years of industrial depression, the number of aliens returning to Europe is much increased, and while no claim is made that these birds of passage are desirable immigrants, it must be admitted that they do not add to our burdens in times of trouble by swelling the army of the unemployed. On the other hand, we have to consider the excess of males of competitive age (15 to 45) among immigrants, and their unequal distribution. Their geographical distribution is such that 86 per cent. are settled in the states east of the Mississippi and north of the Ohio rivers. Their distribution by trades or occupations is also unequal, as shown by the relatively small number engaged in tilling the soil, compared with the enormous number engaged in mining and sweat shop occupations.

One of the chief offenses charged to the immigrant is reduction of our wage standards. There are other factors more potent in depressing wages than immigration, some of which are not connected with it in any way; others are associated with it so intimately that it is difficult to separate them from it. These factors are obscured in the minds of many by the fact of our increasing immigration, and some are prone to charge the sum of their effects to immigration alone.

Cycles of business depression seem to reach us almost periodically, as they do every other country. These are hard to explain and can not be ascribed to any one particular cause.

Immigration falls off very noticeably during these periods, and, in addition, the stream of aliens leaving our ports for Europe is vastly increased. During such periods of industrial depression the wages of the toiler are necessarily reduced. It is not an oversupply of immigrant labor which is responsible for the stagnation, but an unwillingness on the part of the capitalist to invest money in enterprises whose success is doubtful, owing to commercial uncertainty. It is not a lessening of demand, owing to over supply, but often a complete absence of demand for labor, with abandonment of all attempts at production, due to lack of confidence in financial conditions.

The influence of improved machinery upon wage depression can not be over estimated, although its introduction is closely associated with immigration. Improved machinery would probably have been introduced and would have had its effect upon wages in the entire absence of immigration. The use of improved machinery made possible the employment of thousands of unskilled laborers under the direction of a few skilled workers, where formerly the work was done entirely by skilled laborers or mechanics. Its use immensely increased the power of production, and created a new demand for unskilled labor. The effect of machinery has been felt upon wages in the textile trades, woodworking, steel and iron industries, soft coal mining and other occupations. The advent of improved machinery was inevitable, and no labor organization, however strong, could indefinitely clog the wheels of progress by postponing its employment. The immigrant is not responsible for its introduction, for it has been introduced in countries with no immigration problem. He simply took advantage of the demand for labor thus created and played no small part in the wonderful growth of our mining and manufacturing industries. His coming no doubt facilitated the introduction of improved machinery, and it is probable that without this unskilled labor our present position as a producing power would not have been reached for many years to come. The employment of women and children in textile, leather and tobacco trades has demoralized the rate of compensation for male workers in those occupations. Many immigrant women and children take advantage of this practise, but it existed before the immigrants were employed in this way, and to-day thousands of native women and children are employed in factories and mills, especially in the south. The practise is here to stay, and beyond the limitation by law of the age of child workers, can not be stopped. The immigrant's wife and children are not responsible for it, but by means of it increase the family earnings and raise their standard of living.

A depressing influence upon wages is exerted by the competition of the rural factory or shop. The manufacturer in the rural community often receives a bonus, exemption from taxes, free water or other inducements from the municipality. He finds abundance of cheap labor, men, women and children, who can afford to work below the wage scale of the city, because of the lower cost of living. He is thus enabled to place his products upon the market at a cost much below that of the city-made product, and to compete with him the city manufacturer is forced to reduce his wage scale. This competition of the rural shop or factory is felt in tobacco, cotton, silk, leather and many other industries. Many of the industries of the south are of a similar competing character. The wages paid, the standard of living and cost of necessaries are all much below those of the North. This cheap native labor of the south is felt most as a competing factor by the textile industries of New England, who are forced to secure cheap labor for their own salvation.

The difficulty of maintaining efficient labor organization is the cause ascribed by many labor leaders for wage depression. In this difficulty the immigrant has played an important part. The failure of the strike of 1875 in the coal mines, and of the great Homestead strike in the steel and iron industry, is explained by the introduction of alien labor. After years of effort the aliens in the mining fields have been organized successfully and are now, for their own betterment, heart and soul in the movement for living wages. The cheap native labor in the soft coal mines has caused the organizer much more trouble than the alien laborers.

Most of the skilled trades are able to maintain their unions and their wage-standards in spite of foreign immigration. In some occupations, however, the stream of skilled alien addition is so great and so constant, that disorganization and confusion result in the trade, and wages drop to a minimum. In this confusion and disorganization caused by the influx of foreign skilled labor, the clothing trade suffered more than any other industry. So constant has been the stream of foreign tailors to this country that they have now almost monopolized this occupation. The wage scale has descended to a point where the American can no longer compete, and he has been finally forced out of the business as a workman. A revolution has taken place in the manufacture of clothing. The wholesale manufacture of ready-made clothing has superseded the output of the individual tailor shops. Under the present system of wholesale manufacture of ready-made clothing, the work is subdivided into many branches. Formerly a tailor made and completed the garment himself, by reason of skill which it took four or five years to acquire; now the garment passes through the hands of a dozen or more workers, who are each skilled in some particular

branch of the industry. Their skill is acquired in a few months, and they can only do certain kinds of work. This subdivision of labor makes it possible to train and employ almost at once the thousands of new arrivals, and out of the employment of these new arrivals and the conditions resulting from their ever increasing competition arise the sweat shop and its evils. The sweating system produces a condition of affairs in which the operative performs the maximum amount of work for the maximum wage, the length of his working day only limited by his endurance, and, even when he extends himself to the limit, in many cases he can earn scarcely enough to keep him from starvation. This work in addition is performed under the most unsanitary conditions, often in the foul vitiated atmosphere of tenement rooms which are used alike for working, eating and sleeping.

Effective organization is difficult, well-nigh impossible among these clothing workers because of the influx of new arrivals and the employment of women and children in the so-called home work. Legislation has done much to ameliorate sweat shop evils. The workshop in the home is seen much less frequently than formerly, and is fast disappearing. A certain amount of work upon clothing will inevitably be done at home, called 'finishing,' by women who are not entirely dependent upon it, but who increase the aggregate earnings of the family in this way. Much of the work in the clothing trade is now done in shops, especially fitted for the purpose. These shops are more amenable to inspection under our factory laws, and a great deal has been done by state inspectors in this direction.

Another institution charged to immigration, of which we hear almost as much as we do of the sweat shops, is the so-called 'padrone system.' The padrone system is simply the extortion practised by unlicensed Italian employment agents, who, by their knowledge of our language, are in a position to oppress their credulous, ignorant fellow countrymen in a variety of ways. The worst features of the system have been eliminated through the enforcement of our laws, and the remnant of the system would disappear if the Italian immigrants could be distributed to the rural districts, instead of being at the mercy of padroni in the crowded Italian quarters of our cities.

It will be seen that the competition of the newly arrived unskilled laborer with native Americans is indirect. He competes directly only with other alien laborers, who are already settled in the country. On the other hand, the alien skilled laborer competes directly with native Americans. In some trades the foreign arrivals who are skilled come singly or in small groups, and can be taken into the labor organizations without trouble and no reduction in wages results, but when the stream of skilled arrivals of any particular trade is of large size and constant, organization is impracticable. The new arrivals have to

meet in turn the competition of the thousands of the same caliber and often of the same race, who follow close on their heels; demoralization results and wage reduction is inevitable.

The establishment here of foreign standards of living is unquestionably detrimental. The immigrant is tempted by the wages paid laborers here, which are four or five times greater than those paid laborers in Europe; but when he lands here he finds that not only is the class of food which he used in Europe more costly, but that he must increase his dietary to enable him to perform the work required of him. To withstand the strenuous effort, and the output of energy essential to American industrial life, the alien requires meat and other nutritives, in addition to the fruit and vegetables which sufficed for him at home. If he does not thus fortify himself for the struggle he will break down under the strain. The standard of living among immigrants is of course below American standards, but it is being constantly elevated, with a rapidity, among our alien population as a whole, in inverse ratio to the increase of yearly arrivals. Among individual families the elevation of the standard of living keeps pace with their Americanization and their success in life. The immigrant's daily contact with Americans, coupled with the ideas absorbed by his children in American schools, is a potent factor in raising this standard.

GALILEO.

By Dr. EDWARD S. HOLDEN,
U. S. MILITARY ACADEMY, WEST POINT, N. Y.

I.

When the position of a heavenly body changes with such extreme slowness as to leave astronomers undecided as to the change even, and still more as to the direction of the change, it is their custom to compare two observations made at a great interval of time. If the doubt still exists, they affirm with certainty that the position they have measured is invariable, or nearly so, since it is subject to no regular and persistent alteration. Such a method applied to the history of the human mind leads to grave melancholy and discouragement. Men have been ignorant and blind at every epoch. Always we find the same ignorance, the same rash illusions, the same obstinate prejudices.

Toujours mêmes acteurs et même comédie.

Three centuries before our era, a philosopher, Cleanthes, demanded that Aristarchus should be brought to justice for his blasphemies in declaring the earth in motion, and the sun to be the fixed centre of the universe. Two thousand years later, the human understanding had not progressed. The desire of Cleanthes was realized, and Galileo was accused of blasphemy and impiety, in his turn. A tribunal dreaded by all condemned his writings, constrained him to denials disavowed by his conscience, and, judging him unworthy of a freedom that he had abused, deprived him of a part of it, and thought it an indulgence to have left him any liberty whatever.

But history is not to be judged in this way. Events in themselves are of small moment; the impression that events produce is the only revelation of the public consciousness. Never before has its generous aversion for intolerance burst forth so strongly as for the sufferings of Galileo. The story of his misfortunes, exaggerated like a pious legend, has confirmed the triumph of the truths for which he suffered, at the same time avenging him. The scandal of his condemnation will forever vex the pride of those who still wish to put down reason by force; and the just severity of opinion will preserve the unwelcome remembrance as an eternal reproach. But it is necessary to be frank: this great lesson did not cause any deep sorrows. The long life of Galileo, taken all in all, is one of the most peaceful and most enviable that the history of science records.

The foregoing paragraphs translated freely from the life of Galileo by M. Bertrand, perpetual secretary of the Paris Academy of Sciences, expresses so precisely the point of view of this article that I have quoted them in order to have, from the outset, the support of his great authority. And to them may be added the following extracts from the 'History of the Inductive Sciences' of Dr. Whewell, master of Trinity College, Cambridge. The words in brackets are my own.

The heliocentric doctrine has for a century been making its way into the minds of thoughtful men on the general ground of its simplicity and symmetry. Galileo appears to have thought that now, when these original recommendations of the system had been reenforced by his own discoveries and reasonings, it ought to be universally acknowledged as a truth and a reality. And when arguments against the fixity of the sun and the motion of the earth were adduced from scripture, he could not be satisfied without maintaining his favorite opinion to be conformable to scripture as well as to philosophy; and he was very eager in his attempts to obtain from authority a declaration to this effect. The ecclesiastical authorities were naturally averse to express themselves in favor of a novel opinion, startling to the common mind, and contrary to the most obvious meaning of the words of the Bible; and when they were compelled to pronounce, they decided against Galileo and his doctrines. He was accused before the Inquisition in 1615; . . . the result was a declaration of the Inquisition that the doctrine of the earth's motion [was] contrary to the sacred scripture. Galileo was prohibited from defending and teaching this doctrine in any manner, and promised obedience to this injunction [as will be shown later].

But in 1632 he published his Dialogues and in these he defended the heliocentric system by all the strongest arguments which its admirers used. Not only so, but he introduced into this dialogue a character under the name of Simplicius [supposed by contemporaries to have been intended to represent the Pope then reigning, which idea was fully accepted by the Pope himself, especially as the Pope's own words were attributed to Simplicius,] in whose mouth was put the defense of all the ancient dogmas and who was represented as defeated at all points of the discussion; and he prefixed to the dialogue a notice To the Discreet Reader, in which, in a view of transparent irony he assigned his reasons for the publication. . . . The result of this was that Galileo was condemned for his infraction of the injunction laid upon him in 1616; his dialogue was prohibited; he himself was commanded to abjure on his knees the doctrine he had taught; and this abjuration he performed.

. . . The general acceptance of the Copernican system was no longer a matter of doubt. Several persons in the highest positions including the Pope himself [not the Pope] looked upon the doctrine with favorable eyes; and had shown their interest in Galileo and his discoveries. They had tried to prevent his involving himself in trouble by [through] discussing the question on scriptural grounds. It is probable that his knowledge of those favorable dispositions towards himself and his opinions led him to suppose that the slightest color of professed submission to the church in his belief, would enable his arguments in favor of the system to pass unvisited; the notice [To the Discreet Reader] in which the irony is quite transparent and the sarcasm glaringly obvious, was deemed too flimsy a veil for the purpose of decency, and, indeed, must have aggravated the offence.

The foregoing extracts from the writings of authoritative historians of science place the chief events of Galileo's long life in what seems to be the true light. There is little doubt as to the events themselves—except in a single particular, which will be considered in what follows. Much controversy has raged over their interpretation. They must be considered in two regards: First, in respect of Galileo's private and personal experience; second, in respect of the lesson which that experience has taught to the world in general. The remark of Bertrand

that has just been quoted is profoundly significant: *events in themselves are small affairs; it is their effect on the public consciousness that remains and is permanent.* Galileo's private life was essentially peaceful, as a whole even 'enviable.' To the world in general he is, on the other hand, the protomartyr. His trials have opened new roads for human thought, given liberty to science and philosophy, and were the occasion of a final delimitation of the provinces of the church and of philosophy. The modern attitude of mind may be said to take its date from him. It is in this that his greatest service to mankind consists. The astonishing discoveries that we owe to his genius are small matters in comparison.

In what follows the events of his life will be recited. Where there is doubt it will be pointed out. There is no space to discuss controverted points at length. Volumes have already been written on the history of his trial by the Inquisition; on the documents, genuine or fabricated, of this process; on the question whether or no he was put to the torture.* To these volumes reference must be made, once for all, for the original documents and for a discussion of their authenticity. The object of the present chapter is, first, to tell the story of his life, second, and most important, to exhibit its effect upon his own and succeeding centuries. It will conduce to clearness if his private and personal life be separated in thought from his services to mankind in general; if the story of his experience be discriminated from the legend.

The popular legend in its crudest form declared that Galileo, a martyr of science, languished in the dungeons of the Inquisition; defended his doctrines boldly; was tortured; and under bodily torture recanted and abjured; saying, however, at the last, *E pur si muove* before he was again removed to his prison, where his eyes were blinded. If the legend had not taken on this crude shape it would, perhaps, have been less efficacious in the century immediately following his death. As it stands it is almost entirely devoid of truth. The real history is hardly less distressing, but the facts are utterly different.

Galileo was born at Pisa on February 18, 1564, of the noble family of the Bonajuti which since 1343 had been known as the Galilei. In 1445 a representative of the family was Gonfalonier of Florence, and no less than fifteen of its members had served in the Signoria. The father of Galileo, Vincenzio, was skilled in mathematics and especially in music, on which he wrote several treatises. He was poor and

* Among these the reader may wish to consult Martin, 'Galilée, etc.,' 1868; Wohlwill, 'Der Inquisitions Process des Galileo Galilei, etc.,' 1870; L'Epinois, 'Galilée, son procès, etc.,' 1867; Gebler, 'Galileo Galilei, etc.' (English edition), 1879; Galileo, 'Opere, edizione nazionale,' 1890–8.

wished his brilliant son to adopt the lucrative profession of medicine. Galileo's early inclinations seem to have been to become a painter. The boy was educated at the monastery of Vallombrosa, where he learned Latin, some Greek, a little logic. He was an excellent pupil, but as his eyes were affected his father removed him and, at the age of seventeen (1581), sent him to study medicine at Pisa. He was already a clever musician, witty, eloquent, with a strong talent for painting, and had laid the foundations of a literary style which Italians estimate highly. In his later years Galileo knew the poems of Ariosto by heart. His general health was not good, but he was amiable, gay, versatile, fond of society and also very fond of a country life and of his vineyards and groves. He was considerate and liberal to his family, devoted to his children.* His friends loved him ardently, and his enemies were equally constant in their dislike. The characteristics of his maturer life were in evidence throughout his youth also. His powers of observation were extraordinarily quick. He was a philosopher, also, from the first, and very expert in all mechanical matters.

Before the high altar of the cathedral at Pisa hangs a lamp,—a masterpiece of Maestro Possenti. Watching its swingings to and fro one day Galileo, then a student, observed that although the amplitude of the swings diminished the time of oscillation remained the same (1583). From this chance observation resulted the law: The time of oscillation of a pendulum is independent of the amplitude of its swings. If this be true (and it is true when the amplitudes are small), the pendulum can be used to measure, with precision, intervals of time. A hundred of its swings will always require the same time whenever the arc of swinging is not large. The first application of this discovery was the invention of a pendulum suited to measure pulse-beats. Towards the end of his life Galileo endeavored to construct a pendulum clock. He was engaged in this research at the time of his death, aided by his son Vincenzio, who carried on the work. A short pendulum beats more quickly than a long one. The law of the relation of length to period was also discovered by Galileo. It is: The lengths of pendulums are proportional to the squares of the times of oscillation. A pendulum beating seconds is four times as long as one beating half-

* Galileo was never married. He formed an illicit connection with a Venetian woman, Marina Gamba, by whom he had three children, two daughters and a son. His daughters took the veil in a convent at Arcetri. His son married and left descendants. The mother of his children subsequently married one Bartolucci, with whom Galileo was in friendly relations after the marriage. In 1627 Pope Urban VIII. granted a pension to Galileo's son who did not accept it, owing to religious observances necessitated by the grant. The pension was transferred to a nephew and finally it was increased and bestowed upon Galileo himself with the condition that he should adopt the tonsure. This pension was drawn by Galileo till his death.

seconds, therefore. These laws are the basis of horology. They were first fully utilized in the construction of clocks by Huyghens.

A lesson in geometry overheard by Galileo while a pupil excited his deepest interest. Euclid soon became his master and, from this day, his attention to medicine slackened, much to his father's regret. The salaries of mathematical professors were extremely small in those days, while the rewards of successful physicians were very much greater. Owing to his father's poverty, Galileo was withdrawn from the university in 1586, and returned to Florence. It is recorded that at the university he was known as a brilliant, though disputatious, pupil, and was nicknamed 'The Wrangler.' At Florence he lectured before the academy on the situation and dimensions of the Inferno of Dante—a question partly philosophical, partly scientific. It was at this time that he studied the works of Archimedes and wrote a little treatise on the hydrostatic balance. In 1587 he went to Rome and made the acquaintance of Clavius and other scientific men.

In 1588 he had the great good fortune to meet a generous patron, the Marchese Guidobaldo del Monte, and, in the same year, wrote at his request a treatise on the center of gravity of solid bodies. By his influence Galileo was appointed to be lecturer on mathematics in the University of Pisa (1589). His salary was only sixty scudi annually (about $65), and he was obliged to eke it out by giving private lessons. The salary of the professor of medicine was 2,000 scudi. During the years 1589 to 1591 he made those experiments on falling bodies which are the basis of the science of mechanics.

From the time of Archimedes (287–212 B. C.) till that of Leonardo da Vinci and Galileo there had been no progress in theoretical mechanics. Archimedes discovered the theory of the lever: 'Give me where I may stand and (with the lever) I will move the world.' His knowledge of practical mechanics was, no doubt, derived from his famous works of military engineering. All the great buildings of antiquity had been built by processes not unfamiliar to him. All the great basilicas of Europe and all the Gothic cathedrals with their nice system of balanced thrusts had also been erected before the time of Leonardo. The practical processes of engineering were highly developed, therefore, but as yet no one had formulated a theory. That Leonardo comprehended its fundamentals is abundantly shown by his note-books recently published. Every military engineer who had watched the flight of a projectile was aware that the received notions of mechanics would not explain its motions. No theory of the impact of such projectiles had even been proposed. A whole science was to be created. The doctrine of mechanical equilibrium is statics—and this science was founded by Archimedes. The doctrine of mechanical motion is dynamics—and nothing was done in this science till the time of Galileo.

The theories of the lever, of the inclined plane and of the screw were familiar to Leonardo.*

The ideas of Aristotle as to motion and rest were not physical, but metaphysical. An example will illustrate his mode of reasoning which satisfied the scientific world for something like two thousand years. When a stone is thrown from the hand why does it continue to move for a time, and why does it eventually come to rest? Where is the cause of motion—in the hand?—or in the stone? If in the hand, how can the stone continue to move after it has left the hand? If in the stone, why does it ever come to rest? Aristotle's answer is that 'a motion is communicated to the air, the successive parts of which urge the stone onward; each portion of the air continues to act for some little time after it has been acted upon, and the motion ceases when it comes to a particle which can not act after it has been acted upon.' The confusion of this explanation is complete.

The mechanical ideas of Aristotle and of his successors, as to falling bodies, are expressed in these words: 'That body is heavier than another which, in an equal bulk, moves downward quicker.' Transforming the phrase, we may say, that if two bodies, *A* and *B*, are of equal bulk but of different weights, then the heavier body will fall the quicker; or, again, if *A* weighs ten pounds and *B* one pound, *A* will fall faster than *B*. The Aristotelians of Galileo's time further maintained that *A* would fall exactly ten times faster than *B*. Galileo's experiments proved that they fell in precisely the same time. Sixteen hundred years earlier Lucretius had come near to the same truth: "For whenever bodies fall through water and thin air they must quicken their descents in proportion to their weights, because the body of water and subtle nature of air can not retard everything to an equal degree; on the other hand, empty void can not offer resistance to anything in any direction at any time, but must continually give way; and for this reason all things must be moved and borne along with equal velocity, though of unequal weights, through the unresisting void."

While Kepler was determining the empirical laws according to which the planets move in their orbits, Galileo was laying the foundations of the science of mechanics by which, eventually, Newton was to explain why they so move. The foundations of mechanics rest on experiments made by Galileo, at Pisa, on the laws of falling bodies. It was the opinion of the time that heavy bodies fell faster than light ones, and it was a matter of common observation that a square foot of wood reached the ground before a square foot of paper released at the same time. The fact was explained by Galileo as due to the resistance of the air. In a vacuum they would fall at the same time. By crump-

* Leonardo's investigations in mechanics were not published during his lifetime, but a correct theory of the lever was known to him as early as 1499.

ling the paper into a solid ball, it could be made to fall as rapidly as a ball of wood or iron. Experiments of this nature led Galileo to the discovery of the first law of motion, to wit: The velocity of falling bodies varies directly as the time.

At the beginning of the fall the velocity is zero; at the end of the first second, it is a certain quantity which experiment shows to be the same for all bodies. Let us call this velocity g. Galileo's experiments showed that at the end of the second second the terminal velocity was $2g$, at the end of the third, $3g$ and so on. The algebraic expression of the first law is, then,

(I.) $$v = g.t$$

(experiment shows that $g = 9.81$ meters approximately).

The second law of motion refers to the relation of the spaces through which the body falls in different intervals of time; it is: The spaces through which a body falls vary as the squares of the times. All bodies obey this law, also, no matter of what materials they are made up.

(II.) $$s = \tfrac{1}{2}\, g.t^2$$

(s = space, t = time).

At the beginning of the fall the time (t) is zero, and the velocity (v) is also zero. At the end of the first second, $t = I$ and $v = g$ (by I.). The velocity has increased from 0 to g and its average value is therefore $0+g/2 = \frac{1}{2}\, g$. The space traversed at the end of the first second is (by II.) $\frac{1}{2}g$; at the end of the second second, $2g$; at the end of the third second, $\frac{5}{2}g$, and so on. The two laws are not independent but are separated for convenience. They are sometimes united into one, and the law of inertia (also known to Galileo) added in this form: Every body preserves its state of rest or of uniform motion in a right line unless it is compelled to change that state by forces impressed thereon.*

It is this latter law that changed the whole face of science. It was supposed by the ancients and by Copernicus that the normal condition of all bodies was rest; that if they were moving it was because some force was perpetually impelling them. On the earth a pendulum stops because of the resistance of the air and the friction at its supports. Remove the air and annul the friction and it will swing forever until some impressed force stops it, so Galileo announced. Kepler was incessantly trying to conceive how a planet could continue to move in its

* The statement of the law is Newton's. It is implicit in Galileo's laws of falling bodies and must have been understood by Leonardo da Vinci. Kepler, perhaps, anticipated Galileo in its discovery. It is a necessary part of Huyghens's theory of central forces, but it was not clearly enunciated until the day of Newton.

orbit, and was forced to conclude that some inherent energy, perhaps an angel, perpetually acted to keep it moving. Galileo's law announces that if it is once set in motion it will continue to move until some impressed and extraneous force causes it to stop. Motion is as 'natural' as rest, therefore. It happens that on the earth there is no body moving under the action of no force. Falling bodies, projectiles, and the like, are perpetually attracted by the earth's mass, continually retarded by the resistance of the air. It required abstract philosophical reasoning to determine how such bodies would move were the impressed forces removed, and it is this reasoning that is Galileo's chief title to enduring fame. In this respect he changed the whole thought of the world. His telescopic discoveries might have been made by others. There was no man in Italy besides himself who could have founded the new science of mechanics.

Newton added two laws of motion which read: The alternation of motion is ever proportional to the moving force impressed and is made in the right line in which that force acts. To every action there is always opposed an equal reaction; or the mutual actions of two bodies upon each other are always equal, and in opposite directions. His law of universal gravitation is: Every particle of matter in the universe attracts every other particle with a force directly as the masses of the two particles, and inversely as the squares of the distance that separates them.

With these laws as bases of calculation the question may be answered: What orbit will a planet describe about the sun? The answer is, a conic section, an ellipse for example. Again: What will be the law of the motion of each planet in its ellipse? The answer is: Its radius-vector will sweep over equal areas in equal times. Again: In a system of such planets, how will their orbits be related? The answer is: The squares of their periodic times will be proportional to the cubes of their mean distances from the sun. From the single law of gravitation the three laws of Kepler (as above) necessarily follow. Kepler's laws were empirical and were not complete until Newton's discoveries. This brief note explains the logical outcome of Kepler's and of Galileo's researches.

The new laws of motion were expounded to the students of Pisa with fire and eloquence. The theories of Aristotle and of his followers were treated with scorn and contempt. In his zeal for the truth Galileo branded the scientific errors of his colleagues almost as if they had been moral faults. His asperity laid the foundation of enmities that followed him throughout the whole of his life and led to his ruin. It is as true of Galileo as of Roger Bacon that his character was his fate.

How the strictures of Galileo were received by the exasperated Aristotelians may be imagined. If his experiments were to be believed, the words of Aristotle were false. If the philosophy of Aristotle were false in one part it might be false in all. The experiments must therefore be denied, and their author discredited. It is recorded that the experiments were, in fact, denied. The facts of experience were met

with argument. Galileo's retorts were bitter and brilliant, his sarcasms searching and unsparing. Before the end of his three years' engagement as professor had expired, he had involved himself in a hopeless wrangle with his colleagues and with Aristotelians throughout Italy. An imbroglio with John of Medici put him out of favor at court also at this very time. The nephew of the reigning Duke of Florence had invented a machine for dredging the harbor of Leghorn, and the plans were submitted to Galileo, who declared the apparatus to be useless, as indeed it was. He made no friends by this candor and gave another weapon to his enemies which they were not slow to use. The students in the university were incited against him and he was publicly hissed at lectures, so that he felt it advisable to resign his professorship (1591).

He returned to Florence discredited and out of favor. His father died in July of this year, leaving his family in distress for money. Galileo's friend and patron, the Marquis del Monte, warmly recommended him to his friends in Venice, and as a result he was appointed to be professor of mathematics at the University of Padua, for a term of six years, this time at a salary of 72 zecchini, about $90. He remained titular professor for a period of eighteen years, until 1610, his appointment being three times renewed and his emoluments increased to $500. In December, 1592, he entered upon his duties. His lessons embraced a wide range of subjects: astronomy, gnomonics, fortification, mechanics and the like. His lectures were thronged with students. The halls were not spacious enough to hold them all and at times he taught in the open air.

In 1597 he invented his proportional compasses of which he was very proud. His manuscript description of them was plagiarized by one Balthasar Capra, and Galileo's scathing review of the work excited general notice for its bitter satire. He was already recognized as an adversary to be feared.

It has lately been demonstrated that we owe the invention of the thermometer to Galileo. His first instrument appears to have been a crude air thermometer devised in 1595. It was soon (1611) applied by physicians to the diagnosis of fevers and about 1641 to regular meteorological observations of temperature. The scales were arbitrary. The idea was developed by his pupils in various ways. The 'Florentine' thermometers used by the Accademia del Cimento (1657–1667) had straight sealed tubes connected with bulbs filled with spirits of wine. The highest summer heat corresponded to 80°, the lowest winter cold to 20°. So late as 1741 Florentine thermometers were in common use throughout Europe. It was not till 1694 that the freezing and boiling points of water were *proposed* as standard. Fahrenheit's thermometer date from 1709, Réaumer's from 1730, Celsius's (the centigrade) from 1742–3.

In 1604 a new star suddenly appeared in the heavens. It was discovered in October and quickly grew to be brighter than Jupiter. By the end of March, 1605, it had diminished to the brightness of a star of the third magnitude and in about a year it had vanished from sight. Its career was like that of the new star of 1572—Tycho's star. Galileo delivered three lectures on the new star to crowded audiences. He enforced upon the Aristotelians the conclusion that the heavens were not incorruptible, as they maintained. Here was a glaring proof of it. The star had no parallax. Hence it was far beyond our atmosphere. It was no 'meteor,' as they also maintained. These just conclusions were advanced with rasping criticisms of the old philosophy and the breach with his colleagues was widened still further.

In 1597 Kepler sent his *Prodromus* to Galileo, who writes to thank him for it, saying:

> I count myself happy, in the search after truth, to have so great an ally as your self. . . . I have been for many years an adherent of the Copernican system. . . . I have collected many arguments for the purpose of refuting (the commonly accepted hypothesis), but I do not venture to the light of publicity for fear of sharing the fate of our master Copernicus, who, although he has earned immortal fame with some, yet with very many—so great is the number of fools—has become an object of ridicule and scorn.

It is to be noticed that Galileo (like Copernicus himself) dreaded the ridicule of fools. It is probable that neither of them feared the discipline of the church, or even considered it likely to be exerted.

The revolution in men's ideas to be worked by the Copernican system was not understood in the sixteenth century. It was regarded as a scientific hypothesis—an absurd one, contrary to scripture, Tycho Brahe had said. Its theological import was appreciated first by Lutherans and afterwards in Italy. Pope Paul III., to whom Copernicus dedicated his book in 1543, received it 'with pleasure.' A second edition was printed in 1566 without exciting the slightest adverse remark. It was not until the time of Galileo that men began to see that the accepted order of heaven and earth was inverted by the new doctrine. The earth was no longer the center of the universe. The planets were not made for man, who was dethroned not only in science, but in philosophy and theology as well. It remained for more modern times to appreciate that as it was by man himself that man was so dethroned, a new glory had been added to his crown.

All men find it painful to face novel ideas, and it is but natural to seek and find sufficient reasons for avoiding painful thoughts. When they are once familiar, new pleasures are discovered; and not until then do they begin to gain acceptance. Kepler 'shuddered' at the very idea of an infinite universe. Even he had not completely shaken off the Ptolemaic conception of a limited world. The authority of the

Roman Church had been in theory literally universal, and Copernicus limited its world to one small planet, not so large as Jupiter as Galileo showed a few years later. The new doctrine disgraced the dignity of the earth among the planets. The authorities of a universal church could not but feel that their own dignities were attacked by the same blow. Arguments against the scientific truth were forthcoming from every chair of philosophy in Italy, and every theologian could successfully defend the literal sense of Holy Writ against such subtile and wire-drawn interpretations as were subsequently advanced by Foscarini and Galileo. I imagine the state of mind of their more intelligent contemporaries to have been one of interested bewilderment. The less intelligent were repelled and offended. The mass of pious christians was outraged and indignant. The Pope (Urban VIII.) and most of the cardinals sincerely believed that incalculable injury would result to the church from the promulgation of an opinion flatly contradicting the literal words of scripture. It was not until the discoveries of the telescope came to confirm the hypothesis of Copernicus that all these questions were pressed home for decision.

(*To be continued.*)

RADIOACTIVITY AND MATTER.*

By CLEMENS WINKLER.

THE discovery of radioactivity has opened to physical and probably also to chemical research a field of extraordinary and peculiar promise. We seem to have a source of energy which flows spontaneously for unlimited time without tangible indication of its source; effects of energy are exhibited which neither in essence nor in phenomena resemble those previously known; substances are presented which seem to be of an entirely new kind, though they resemble our oldest and best-known elements so closely as to make their distinction difficult. The most prominent of these substances is radium, which, in the opinion of its discoverers, may be considered a new chemical element and which has been recognized as such by the International Atomic Weight Committee by giving it a place in their table of atomic weights for 1904.

Much more indefinite are the relations of the other radioactive substances thus far made known. The existence of polonium, discovered by P. and S. Curie, was for a time considered dubious, but seems to awake to new life in the radiotellurium of W. Marckwald. On radiolead voluminous researches have appeared which are especially noteworthy in chemical respects, still they do not yet authorize us to recognize a new element with certainty, even if we disregard the objections raised by F. Giesel against these researches. The same may be said of the actinium of A. Debierne and other radioactive substances, such as are supposed to have been detected in the earths of the cerium and yttrium group.

This uncertainty may be understood if we consider that for the researches thus far made only very small amounts of pure or merely enriched materials have been available, which has made the chemical investigation very difficult. The great fascination of tracing the observed phenomena of radioactivity by means of the sensitive photographic plate, the electroscope and the phosphorescent screen had quite naturally made the investigation of the chemical behavior of the substances in question a secondary matter which, while it has not been entirely overlooked, yet has not received that degree of attention that formerly was bestowed on the determination of the characteristic properties of newly discovered elements.

---

* Translated from *Berichte der Deutschen Chemischen Gesellschaft.* The author, best known by this discovery of the rare element *Germanium*, died Oct. 8, 1904, at Dresden.—G. D. H.

In the rather simple working up of the raw material containing radium, the treatment of barium has in the main been followed. Subsequently, the utilization of certain differences in solubility has permitted fractional crystallization and we have thus learned of a special spectrum of radium. But it is questionable whether the spectrum reaction can claim a decisive weight. For a substance, which in so minute proportions has been extracted from so complex a material as the residuals of Joachimsthal, the spectrum might readily prove deceptive. There seems to be very little correspondence between the spark-spectrum for radium obtained by Demarçay, and the flame spectrum described by F. Giesel, while the reddish-orange lines in the radium bromide spectrum, as well as the red coloration which this substance imparts to the flame, make it not impossible that some alkaline earths may have remained in the final residue examined. Besides, no radium compounds have been sufficiently investigated, nor have any chemical reactions been detected specifically peculiar to radium. The determination of its atomic weight has been decisive in recognizing radium as a distinct element, especially as this atomic weight was found to be exceptionally high.

Radium lead has been examined chemically more thoroughly, and yet no noteworthy differences have been discovered between its reactions and those of common lead. Only a great difference in atomic weight seemed to exist. The atomic weight of radiolead was determined by ascertaining the amount of sulphuric acid in its sulphate. It was found to contain 41.85 per cent. of SO_4, while lead sulphate contains only 31.71 per cent.

Assuming that radiolead is quadrivalent like thorium and uranium, its atomic weight from the above analysis would be 260.2, that of lead only 206.9. But this determination seems of doubtful correctness, because the sulphate obtained has not been heated to a beginning red-heat, but has only been dried to 400–420 degrees. At so low a temperature experience has shown it is impossible to remove all adherent sulphuric acid, so that it is not strange that a higher per cent. of sulphuric acid remained. The atomic weight of radiolead can not be deduced from such determinations. Also the supposed discovery of other elements (such as the much hunted for ekamanganese of Mendelejef) can not be established upon the result of such faulty determinations.

Indeed the chemical researches made can not be considered sufficient, however much we may admire the other researches made on the radioactivity of matter. Even the results obtained by fractioning can only be used with extreme caution, because they may lead easily to false conclusions. When the discovery of spectrum analysis had excited the scientific world as it is to-day excited by that of radioactivity, it was

seriously supposed that calcium had been decomposed, because the green line of its spectrum had been made to disappear by fractioned precipitations of its chloride, and crystallographers on this ground tried to find reason for the extraordinary richness of the crystal forms of calcite. Similar pardonable errors may also occur in other cases, though we do not mean to assert that such errors have actually been committed in the fractioning of radioactive substances.

But we must be permitted to ask whether it is really justifiable to assume the presence of a new element in a substance for the sole reason that this substance is radioactive. It would certainly be surprising if every one of the numerous, long known chemical elements, which show radioactivity, were to contain also an elementary associate of almost exactly the same chemical character. Against such a supposition we can mention many reasons, entirely independent of the fact that such a supposition is in conflict with all general experience and the hitherto unshaken idea of the nature of chemical elements. Uranium—one of the elements in question—is certainly a typical element, yet, according to William Crookes, it can be separated into an active and a non-active fraction by merely treating its hydrous nitrate with ether, or by fractional crystallization or by fractional ignition—and at the same time these fractions are said to show no chemical differences whatever. Béla v. Lengyel who doubts the existence of radium, succeeded in making barium active by heating its nitrate with uranylnitrate, and Henry Becquerel prepared a strongly active barium sulphate by precipitating by sulphuric acid a barium chloride solution to which uranyl chloride had previously been added; in this case the activity of the uranium compound had at the same time diminished. Further K. A. Hofmann and E. Strauss have obtained inactive fractions from active uranium compounds; on the other hand they succeeded in temporarily withdrawing from uranium its activity by means of barium or bismuth compounds. Especially remarkable are the experiments of A. Debierne, which have been conducted in a similar manner with actinium, and by which it was proved that it is easy to make active the compounds of barium so that they scarcely differ from those of radium, except that they do not give a radium spectrum. The active barium is said to stand between barium and radium, its anhydrous chloride is self-luminous like that of radium, and may equally well, by fractional crystallization, be separated in a more active and a less active portion.

By induction alone such remarkable phenomena can hardly be accounted for. The objection raised by F. Giesel against Béla v. Lengyel, namely that the activation of barium first produced by the latter might be due to some radium contained in the uranium salt used, is disproved by the fact stated, that under other conditions the same result even in a much higher degree was obtained.

And what are we to say of the supposed material emanation of radioactive 'elements,' of their instability, of their decomposition by splitting off of helium and of the decomposition of the elements themselves? Until now there has not been furnished any demonstration whatever that elements of high atomic weight, to which gold and platinum certainly must be counted, are polymers of elements of lower atomic weights, and that they decompose into such. The idea of a chemical element in the old sense remains still unshaken, and it will require much more thorough chemical experimental research than those produced thus far, to disturb it. On the contrary, it appears from day to day more plainly, that radioactivity seems to be extremely widely distributed, and this observation leads us to the question whether radioactivity may not be simply a purely physical phenomenon, which may be exhibited by matter without in any way modifying its chemical nature, comparable to the magnetism of magnetic iron ore, which, like radioactivity, may be intensified, transferred, apparently destroyed and again called forth, and which, at the same time, also represents a mysterious manifestation of energy, without leading any one for a moment to imagine the existence of another element in magnetic ferroferric oxide not existing in the non-magnetic iron oxide. The idea of an elemental material difference was not thought of by any one, when Fr. Heusler succeeded in making magnetic alloys from unmagnetic metals such as manganese, tin, antimony and aluminum. Also in the case of radioactivity we should be free of material differences if the statement of F. Richarz and Rudolf Schenck should remain without valid objection, namely, that oxygen when ozonized becomes radioactive, so as to act upon the photographic plate, to make Sidot's blende (though only this kind of sphalerite) glow intensely and, like radium, to develop heat.

Considering the radium-craze now afflicting the world and affecting non-scientific circles especially, there is something humiliating to the chemist, after six years have elapsed since the discovery of radium, to say no more than that it resembles barium so closely that it can not be distinguished except by its higher atomic weight and its remarkable independent radiation. The chemical individuality of radium remains almost entirely unknown; nevertheless it is constantly sought, especially in those regions where pitchblende deposits occur, and where they already dream of developing radium ores and a future radium industry. So far as known, the occurrence of radioactive substances is tied to that of uranium. This is in the highest degree surprising and can not be understood if we are to assume the presence of special elements. Though the co-occurrence of certain elements is not uncommon and may be explained by their position in the system, their valence, the isomorphism of their compounds and other resemblances,

we nowhere meet such an exclusiveness as here would be brought to view. An exception might possibly be made as to the thorium, the radioactivity of which, according to G. F. Barker, is independent of its co-occurrence with uranium. However K. A. Hofmann and F. Zerban contradict this opinion, and F. Zerban believes that he has detected a small amount of uranium in the monazite-sand supposed entirely free from it. The method he used is not quite unobjectionable; it was originally devised (by Laube) for the working of uranium residues and not for analytical purposes.

The material thus far used for obtaining radium and other radioactive substances has mainly been the residue left by the K. K. Austrian Uran works after extracting uranium from pitchblende. This residue remains after pitchblende has been roasted, ignited with soda and niter, and extracted with water and dilute sulphuric acid. It consists mainly of gangue, silica, ferric oxide, basic iron sulphate and lead sulphate, but contains also some bismuth and silver. It amounts to 40 per cent. of the uranium ore worked, and we may estimate that in the 50 years of their existence the uranium works have dumped 150 to 200 tons of this residue. It is most difficult to estimate the total amount of radioactive substances in this dump, but the amount of radium will count only by grams, that of radiotellurium only by fractions of a gram.

The residue referred to possesses 4.5-fold the activity of metallic uranium. According to S. Curie, 1,000 kilos of the residue yielded 10 to 20 kilos crude sulfates of 30 to 60 activity, and these again 8 kilos of barium chloride containing radium also of 60 activity. This seems to prove that the radioactivity does not keep pace with the concentration of the barium compounds, but lags far behind. A reliable measure of the radium-amount is not furnished. Even a preparation of 3,500 activity must have consisted mainly of barium chloride, since it yielded 140 for the atomic weight which is only slightly in excess of that of barium. As to the activity of the purest radium chloride, we find no statements, but it is said that the best radium preparations have an activity of 50,000 to 100,000 times that of uranium.

Now arises the question: in what form of combination is radium contained in pitchblende, and in the final solution of the residue? In the latter it is certainly as sulphate, probably also in the former, since heavy spar is most commonly associated with pitchblende. Since now the solubility of the sulphates of the metals of the alkaline earths diminishes with the increase of the atomic weight, radium sulphate ought to be the most insoluble of all in this group. From this and from the isomorphism of barium and radium compounds, we must conclude that the heavy spar associated with pitchblende really must carry the radium of the Joachimsthal ores. But William Crookes has been un-

able to find any radioactivity in any of the heavy spars examined by him, and even if he did not specially examine heavy spar from Joachimsthal, the above result would be strange, since all other experience of the co-occurrence and mutual replacement of the elements would preclude that radium, in contradistinction to calcium and strontium, would be prevented from association with natural barium compounds, if it really were an element closely resembling barium. But if radioactive heavy spar occurs, its radium contents would pass into the barium chloride manufactured therefrom, and in that case it would not be difficult to separate it by fractional crystallizations on a large scale, however minute the radium contents might be. The experiment made by S. Curie with 50 kilos of commercial barium chloride has, however, given a negative result.

But even if radium for reasons at present unknown should exclusively follow the occurrence of uranium, it ought to occur in relatively wide diffusion at least in the Erzgebirge. For even outside of the deposits of pitchblende, such as those of Joachimsthal or of Johanngeorgenstadt, Schneeberg, Annaberg and Freiberg, one finds in the region specified frequently uranium-carrying rocks, especially granites, the uranium contents of which are indicated by an incrustation of calcium uranite acting on the sensitive plate and often visible in the crushed rocks used in the streets. It therefore appears not impossible to find in that region, where also bismuth is widely diffused, a new material which might successfully be worked for the extraction of radioactive substances. By producing radium in the pure state in larger quantities and by the thorough study of its chemical behavior we might possibly not only attain knowledge of the essence of radioactivity, but also place the existence of radioactive elements of individual character and definite chemical behavior beyond doubt.

EDUCATIONAL PROBLEMS.

BY THE RIGHT REV. THE LORD BISHOP OF HEREFORD, D.D., LL. D.,
PRESIDENT OF THE EDUCATIONAL SCIENCE SECTION OF THE BRITISH ASSOCIATION.

WE hear much more than formerly about the public schools being the best training-place for good citizenship. Therefore, say the critics, it is reasonable to inquire how far their educational system, their ideals, their traditions, their fashions and the pervading spirit of their life fit the mass of their pupils intellectually and otherwise for the duties of citizenship and for grappling in the right spirit with the problems that will confront them. 'Any careful observer,' says one of these writers, himself a loyal public-school man, and intimately acquainted with school life, "any careful observer, who has studied the political moods and opinions of the middle classes in this country during the past few years, can hardly have failed to notice two obviously decisive influences: an ignorance of modern history and a want of imagination. For both of these defects the public schools must bear their full share of blame. It may be doubted whether any other nation teaches even its own history so little and so badly."

The result is that 'to the average public school and university man the foreign intelligence in his daily paper is of less interest than the county cricket; and though events of far-reaching importance may be happening almost under his eyes he is in the dark as to their significance.' "As regards the duties and aims of citizenship in all the various affairs of his own country, political, social, economic, he goes out from his school almost wholly uninstructed by the lessons of history, or by any study of the life and the needs of our own times. Again, as it is urged, the lack of imagination is hardly less dangerous to us than lack of instruction in the lessons of history and the social conditions and needs amongst which we have to live and work. No doubt the gift of imagination is a natural gift,—it can not be created. But, given the thing in the germ, it can be stimulated and developed, or starved, stunted, or even crushed out. No system of education that neglects it is even safe. For, without it, principle becomes bigotry and zeal persecution. It is conscientiousness divorced from imagination that produces Robespierres. Now, it is precisely here that we should expect the public schools to be most helpful, for it is through literature that the faculty is most obviously cultivated, and they all profess to give something of a literary training. But though the intention is excellent the performance is often terribly meager." What-

ever may be thought of such criticisms as these, which come from within our public-school life, it is, I imagine, generally agreed by those who know both our national needs and the work and influence of our public schools, that there is much room for improvement in regard to methods of teaching, the cultivation of intellectual interests and tastes, and the stimulating habits of thought in the majority of their pupils. In close connection with these considerations there are two questions of practical importance which deserve a prominent place in any study of our public-school education.

The first of these is whether it is good for all boys alike to continue their life at school, especially at a boarding school, up to the age of eighteen or nineteen; and the other is whether more encouragement and pains should not be given to developing the best type of day school, or, to put it somewhat differently, whether the barrack life of the boarding school has not, through fashionable drift and class prejudice, become too predominant a part of our English education at the expense of the home life with all its finer educational influences.

As regards the first of these questions, it will be remembered that Dr. Arnold considered it a matter of vital importance to expedite the growth of a boy from the childish age to that of a man. In other words, the boy should not be left to grow through the years of critical change from fourteen to nineteen without special regard to his growth in intellectual taste and moral purpose and thoughtfulness. His education during these critical years should be such as to rouse in him the higher ambitions of a responsible manhood.

Does, then, the actual life of a public school really conduce to this early development in the majority of cases? My own experience has led me to the conclusion that it can not be confidently held to do so. The boys in any of our public schools may be said to fall into two classes—those who in due course reach the sixth form, and during their progress through lower forms have an ambition to reach it; and, on the other hand, a numerous class who do not expect to rise to the sixth, don't care about it, and never exert themselves to reach it.

For the first class, I doubt if any more effective preparation for life has been devised than that of our best English schools; but the case of the second class is somewhat different. Many of these come to the end of their school time with their intellectual faculties and tastes and their sense of responsibility as men to a great extent undeveloped. From sixteen to eighteen or nineteen their thoughts, interests, and ambitions have been largely centered in their games and their out-of-school life, with the natural results that their strongest tastes in after life are for amusement and sport. Some of these boys, after loitering at school to the age of eighteen or nineteen, go to the university as passmen, some begin their preparation for the work of a doctor or a

solicitor, and many go straight from school into city life as men of business; and nearly all of them suffer from the lack of intellectual and moral stimulus during these later years of their school life.

Now many of these boys could without difficulty pass the entrance examination to the university at sixteen or seventeen, if well and carefully taught; and I have long held the view that such boys would greatly benefit by going to Oxford or Cambridge at the age of seventeen, or even sixteen, if suitable arrangements could be made. It was with this conviction in my mind that I published a scheme showing how this experiment might be tried about twenty years ago. The interval has confirmed me in the opinion that it would be a distinct gain to many boys to take advantage of such a scheme if made available. They would go out into the world from the university at the age of twenty far better equipped and prepared for life, both as regards knowledge and interests, tastes and character, than by going straight from school at nineteen.

And looking to my own University of Oxford, I see no reason why such younger students should not be safely received. There are at least three colleges in that university which would find it easy to adapt their arrangements so as to secure this. Each of these colleges has a hall in connection with it, well suited for the residence of a college tutor who might have special charge of these younger students, residing in the hall during their first year with somewhat stricter rules as to ordinary discipline and liberty, but in all other respects exactly on a par with the senior undergraduate members of the college.

On the subject of the day school, as compared with the boarding school, a subject which has not hitherto received the attention it deserves, I may venture to repeat here what in substance I have said on other occasions. Many parents are so situated that they have no choice in the matter; but to the educational inquirer it is a question of much interest and importance. The boarding school is admitted to excel in turning out strong, self-reliant, sociable, practical men of affairs, men who have learned by early experience not to think or make too much of small injustices, to rough it, if need be, with equanimity and cheerfulness, and to count it a man's part to endure hardness in a manly spirit. It is a fine type of character which is thus produced, at its best; but the best is not always seen in the result, and the system too often produces an undue deference to public opinion, a spirit of moral compromise and a loss of moral enthusiasm. The human soul in its finer parts is a very sensitive thing, and I do not think the barrack life of an average boarding school is always the most favorable for its healthy growth.

As I look back over the school days of my own pupils I feel that those of them had, on the whole, the best education who grew up as day

boys in good homes at Clifton College. There they enjoyed all the advantages of the cultivated home, which I need not here enumerate, and at the same time, through the arrangements we made for them, all the best elements in the life of a great boarding school. In the upper school of 500 boys, we had about 160 day boys living at easy distances from the school. These boys were divided into two houses—North Town and South Town—about eighty boys in each house, and they were treated for school purposes just as if they were living together in a boarding house. They were under the same rules as boarders in regard to hours of locking up, or the bounds beyond which they might not go without a note from their parents giving express leave. Their names were printed in a house list, a master was appointed as their tutor, whose duty it was to look to their educational needs and progress, to their reports and conduct, just as if they had been boarders and he their house master. Each house had its own room or library on the college premises, with books of reference, and so forth, for spare hours, and took its part with the boarding houses, and held its own in all school affairs, games and other competitions. And my experience of this system compared with others has led me to the conclusion that the form of education which may on the whole claim to be the best is that of a well-organized day school, in which it is clearly understood to be the duty of the masters to give their life to the boys in school and out of school, just as if they were at a boarding school, and in which the boys are distributed into houses for school purposes, just as if they were living in a boarding house. Under such a system they get the best of both worlds, home and school.

From the public school we pass naturally to the universities, and the first question that meets us is the influence they exercise on school education, through their requirements on admission or matriculation and the bestowal of their endowments and other prizes. On this part of my subject I have seen no reason to alter or modify what I said at Glasgow three years ago, and therefore I merely enumerate and emphasize the suggestions which I put forward on that occasion for the improvement of education both at school and college. I hold that it would be equivalent to pouring a new stream of intellectual influence through our secondary education if Oxford and Cambridge were to agree on some such requirements as the following:

1. In the matriculation examination (*a*) candidates to be free to offer some adequate equivalent in place of Greek. (*b*) An elementary knowledge of some branch of natural science, and of one modern language to be required of all candidates. (*c*) A knowledge of some period of English history and literature also to be required of every candidate, and ability to write English to be tested. (*d*) The examination in Latin and any other foreign language to include questions on

the subject-matter of any prepared books offered, some questions on history and literature, and translation of easy passages not previously prepared. (*e*) Marks of distinction should be given for work of superior merit in any branch of this examination, as, indeed, of every pass examination conducted by the university. Candidates should not be excluded from residence before passing this examination, nor should they be required to pass in all subjects at the same time; but the completion of this examination would be the necessary preliminary to entry for any other examination required for a degree.

2. On the question of endowments and the minimizing of waste in the administration of them there is much to be said, and I would suggest for consideration: (1) That, as a rule, open scholarships and exhibitions might be reduced to free tuition, free rooms and free dinners in hall, or thereabouts. (2) That every holder of an open scholarship or exhibition, whose circumstances were such that he needed augmentation, should, on application, receive such augmentation as the college authorities considered sufficient. (3) That care should be taken to discourage premature specialization at school.

For this end it should be required that no scholar should enjoy the emoluments of his scholarship until he had passed the matriculation examination described above; and a fair proportion of scholarships should be awarded for excellence in a combination of subjects. The universities might also do good service in the way of stimulating secondary education, if some small proportion of their entrance scholarships were distributed over the country as county scholarships, on condition that the county contributed an equal amount in every case. In this way some equivalent for the endowments, so cynically confiscated by the education act of 1902, might be recovered and used for the benefit of poor and meritorious students.

Other reforms, which would, as I believe, be productive of valuable results, are the requiring from every candidate for a degree a knowledge of some portion of our own literature and history, and the encouragement of intellectual interests and ambitions by abolishing all purely pass examinations. A pass examination, in which the candidates are invited simply to aim at a minimum of knowledge or attainment, is hardly worthy of a university. The opportunity of winning some mark of distinction in this or that portion of what is now a pass examination would frequently rouse some latent ambition in an idle man, and transform the whole spirit of his work. Thus a modest reform of this kind might be of practical benefit to the nation by helping in its degree to intellectualize the life of a great many of our young men, and draw out unsuspected interests, faculties and tastes.

My observations have run to such a length that I must, perforce, conclude, leaving untouched other aspects of university education and

training, whether in the old or the new universities, as also the whole subject of the higher education of women, and its proper relationship to traditional systems of instruction and study, framed and intended for men. And my last word is a word of practical inquiry. How is this section to be made of most value as an instrument of educational progress? I leave the answer to this question to those more competent to give it, merely putting on record my own feeling that it may do a valuable service and supply one of our special educational needs, if the working committee of the section, enlarged by the addition of various representative persons, makes it a duty to collect and publish year by year in succession a series of papers, the best that can be written by recognized authorities, on the chief branches of our English education, dwelling on its immediate and pressing needs, and how best to supply them. To do this the committee should set to work systematically, commencing in October with monthly meetings, and formulating, without delay, the scheme or series of papers to be prepared and presented to the next meeting of the association.

THE UNITED STATES PHARMACOPŒIA.

By H. C. WOOD, M.D., LL.D.,
PRESIDENT OF THE UNITED STATES PHARMACOPŒIAL CONVENTION.

UNDERLYING our civilization, and often very necessary to our daily life, are agencies unrecognized by the general mass of humanity. Among these is a little book known as the 'United States Pharmacopœia.' It concerns most nearly the medical profession, but perhaps most vitally the general public. Probably four doctors out of five have no clear, correct conception of the Pharmacopœia, its intent and scope; whilst the ordinary citizen does not know of its existence. I have thought perhaps a short article concerning it might not be uninteresting to the readers of the THE POPULAR SCIENCE MONTHLY, and the concurrence of the editor in this belief has led to the present dictation.

The Pharmacopœia is an official standard list of drugs, in which is given so much of their natural history as may be necessary to enable the apothecary to judge of the genuineness and purity of an offered sample, and in which is also given a list of the proper preparations for use of these drugs, with the methods of the making of these preparations. The intent of the Pharmacopœia is to insure genuineness and purity, proper methods of preparing, and uniformity of strength in the preparations. A common, fallacious belief is that Pharmacopœial recognition means that the drug recognized is of value; the fact is that the United States and other Pharmacopœias have in them numerous drugs of very little use. The nature or *motif*, so to speak, of a pharmacopœia is not to distinguish between worthy and worthless drugs, but to see that a drug which is asked for is as sold by the apothecary pure, and that proper preparations of uniform strength are made by the apothecary.

The question which the framers of a pharmacopœia ask themselves, is not is this drug of value, but is there a demand for it by the profession of medicine? If five thousand doctors in the United States believed brick-dust to be a valuable remedy, and habitually used it, brick-dust would have to go into the pharmacopœia. Witch-hazel is probably as active and as useful as is brick-dust, but witch-hazel is a fad, and is enormously called for, and so witch-hazel must go into the pharmacopœia. The pharmacopœia exists for the purpose of requiring the apothecary to give in the first place pure brick-dust or pure witch-hazel when asked for; and in the second place uniform preparations of these remedies.

Every European country has its own pharmacopœia, prepared by

governmental officials; or, in the case of England, by a board especially authorized by the government. One of the peculiarities of Anglo-Saxon civilization is the performance by volunteer bodies under sanction of law of functions which are really governmental. Witness the Brethren of the Trinity, who control and manage the lighthouses of England; witness, also, the United States Pharmacopœial Convention, an incorporated society, which controls the United States Pharmacopœia. Little by little, now in customs regulations, now in pure food bills, now in this, now in that form, without any definite prearranged specific legislation, the United States Pharmacopœia has come to have the force of law in the United States. In the Latin countries the result of such a method would probably be bad; in the Anglo-Saxon lands with the habit of submission of the individual to the majority, the present method has been successful, and probably more successful than direct governmental rule would have been. The United States Pharmacopœia scientifically and practically ranks with any in the world, and obedience to its mandates in pharmacy and in medicine is universal.

The first attempt to make a pharmacopœia in the United States was in 1820; the result was not fortunate, but in 1830 a second edition was prepared which commanded the respect of the profession and was generally accepted. Before this period, if a doctor wrote for a tincture he would get it in one strength in Philadelphia, another strength in New York; or, perchance, the apothecary on the right side of Broadway would give him one strength of preparation, whilst his rival on the other side of the street would put up an entirely different article. What was formerly nationally true is now true internationally. A prescription written in New York for a certain much used poisonous remedy would be put up three times the desired strength in Montreal, where the British Pharmacopœia is in vogue. Arsenical preparations having the same name vary in strength from 1 in 10,000 to 2 per cent., according to the national standard in accordance with which they have been made. The growing freedom of intercourse among nations has made this situation intolerable, and various efforts have been put forth to correct the evil. At last the Belgian government, by summoning the International Conference for the Unification of the Formulas of Heroic Medicines, at Brussels, apparently solved the difficulty. In this conference, which was official and diplomatic in nature, each government of the civilized world was represented by a physician and a chemist or pharmacist and after much talk standards of strength were finally agreed upon for all very potent drugs, and pledges were made by most governments that the National Pharmacopœias should be made to conform. The new United States Pharmacopœia is on the eve of printing; the Committee of Revision has adopted the results of the Brussels conference, and it will be the first National Pharmacopœia of International scope.

THE MOSQUITO INVESTIGATION IN NEW JERSEY.

By Professor JOHN B. SMITH, Sc.D.,
RUTGERS COLLEGE.

WHEN, a few years ago, it began to be generally realized that mosquitoes besides being sources of annoyance, were also dangerous to life and health because of their relation to certain diseases, the question of whether or not control or even practical extermination was feasible began to be seriously considered. Not until then was it realized how little was actually known of these pests and that, as a matter of fact, only a few species had been followed throughout their entire life cycle. It was assumed that all the species of the same genus had approximately the same life history, that the adults had practically identical habits, that what had proved successful in one locality would answer as well in all others, and that each locality with sufficient energy might secure exemption for itself.

The little book on 'Mosquitoes' by Dr. L. O. Howard, issued in 1901, summarizing what was then known, was published at the psychological moment and exerted an enormous influence. Mosquito brigades were formed, and improvement and other societies began work enthusiastically. New Jersey has always had something of a reputation in the mosquito line and at several points active work was begun. There were not wanting those that lacked faith, however, and there was abundant ridicule for those engaged in the work which, by the way, did not turn out as well as had been expected. We had now three classes in the state—the unbelievers and scoffers who were in the vast majority; the enthusiasts who believed firmly in local work, who formed a small but powerful minority, and a yet smaller class who thought that there might be a chance to get money out of it and who urged improvements that they might be engaged to carry out.

As the entomologist of the Agricultural Experiment Station, as well as in his capacity of state entomologist, the writer followed some of this early work, rather as a sceptic than otherwise; but after a season's observation found reason to believe that while eventual success in the direction of mosquito control could probably be obtained, the factors of the problem were not understood and that much work and money was being wasted or misapplied. The danger was that if failure resulted through ignorance the entire movement might be discredited and delayed.

Presenting the matter to Dr. E. B. Voorhees, the director of the station, he was authorized to ask the state legislature for a sum of money sufficient to make such a study of the problem as might be necessary to enable him to make practical recommendations, suited to conditions as they actually existed in New Jersey. Though at first inclined to treat the matter as a huge joke, the law-making body did pass the necessary act appropriating ten thousand dollars for the purpose declared, and this amount, it was intended, should cover two years of work; the minimum of time considered necessary. As a matter of fact it was spread over three years and the investigation is now completed. The detailed report is in the hands of the governor and will be printed in due course; but it may be interesting to summarize some of the conclusions for general information.

It is positively demonstrated that of the thirty-five species of mosquitoes occurring in New Jersey only a few are ever troublesome, and that not more than half a dozen need be considered from the practical standpoint. It has been further found that in this state the mosquito is not a local problem and that in many cases the pest that makes porches uninhabitable at night was bred miles away.

Beginning at the head of Newark Bay, the coast extending southward is edged with a fringe of salt marsh, broken only for a short stretch along Raritan Bay, and from Long Branch to Point Pleasant; and even here every stream has such an edging. Beginning at Bay Head there is an outer bar or strip of sand varying in width from half a mile to two miles or more, broken at irregular intervals but reaching to Cape May. On this narrow shore strip summer resorts like Seaside Park, Barnegat City, Beach Haven, Atlantic City, Ocean City and many others have developed and there is no better beach in the world for bathing and other aquatic sports. Between this outer fringe and the mainland is an area of low marsh, broken into islands by channels, with bodies of water, some large like Barnegat Bay and Great Bay, the majority small. Broad stretches of such marsh also extend along the large rivers of South Jersey so far as the tide makes the water distinctly brackish. Along the Delaware Bay shore the mainland extends closer to the water's edge and the salt marsh areas are smaller, and they gradually disappear along the banks of the river going north, as the water becomes fresh. Altogether there are many thousands of acres of such marsh and on it, in water ranging from fresh to salt, breed four species of mosquitoes. They breed there and nowhere else in the state; but practically two of these salt marsh forms dominate the country for from twenty to forty miles back. In other words they migrate in immense swarms from the places where they were developed and live for weeks or even months in places where, but for them, mosquitoes would be unknown.

The two troublesome species are *Culex sollicitans* and *C. cantator.* A third species, *C. tæniorhynchus* is also a migrant, but occurs in much smaller numbers and does not fly so far. The fourth, *C. salinarius* does not seem to migrate. Except the last, all these species lay their eggs singly in the marsh mud, not in water, and these eggs will maintain their vitality for months during the summer and remain unhatched during the winter. But when they become covered in summer by a spring tide or a heavy rain they hatch within an hour or two, and millions of wrigglers will be found on a marsh after a storm, where none were seen the day before. In a week these wrigglers are ready for the change to pupa and adult. After the adults have hatched, the first warm sultry night sends swarms numbering millions over the surrounding country. Few of these ever get back and none that leave the marsh finally ever reproduce their kind. In *C. sollicitans* only the females migrate and all those that were examined proved sterile; the migratory instinct replaces the desire to multiply. In *C. cantator* both sexes fly; but the males drop out after a few miles have been covered, and the females are sterile as a rule; a few exceptions have been found.

It might seem that having said so much, I had placed the problem of control beyond reasonable hope of practical solution; but the statements are yet incomplete and were left so to bring out forcibly the fact that it is no local matter: it is one with which the state must deal comprehensively. In truth not ten per cent. of that vast marsh area breeds mosquitoes at any time, and even a breeding area is not uniformly bad. The mosquito demands water free from fish or predatory insects of all kinds, that shall remain for at least a week. As a rule wherever tides go, the little species of *Fundulus* or 'killifish' will go and where they go no wrigglers can exist. Wherever fiddler crabs inhabit a marsh area, and there are thousands of acres so inhabited, their holes drain it completely and afford no chance to breed. It is usually at the edge of the highland, where the tide water works in through grass so dense that it bars fish and fills depressions, that the mosquitoes get their best chance and in a number of surveyed areas it was only the edge of the marsh that was reported dangerous. Other danger spots are the irregular, rather high marshes rarely covered by tides, which dry out completely at times, killing all aquatic life, and then fill all depressions by a heavy storm. Cat-tail marshes when they are at all dense are safe from mosquito breeding.

A very thorough survey of the entire salt marsh area determined that not over ten per cent. of it is at all dangerous, and the question arose, what can be done to make that portion safe. Of course any scheme that provided for the reclamation of the marshes and made them available for agricultural or other industrial purposes would also

eliminate mosquito breeding places; but that sort of reclamation is expensive and the total bill would be so great as to make it impossible to obtain consideration from any legislature. For the purpose of preventing mosquito development, reclamation is not necessary; it needs only such works as will enable all surface water to drain off completely in less than a week, or as will fill all depressions to a general level, whatever that general level may be.

The average marsh bottom is a tough clayey mud of variable depth, overlaid by a turf from six inches to a foot or more in thickness. This material is like a huge sponge from which the water will run out if it gets a chance, and which will absorb an enormous quantity of surface water. Its texture is also such that it will maintain even a narrow ditch perfectly and, if it is deep enough—two feet or more—no growth will start from the bottom. For slow drainage a ditch six inches wide, that will affect from thirty to fifty feet on each side can be cut by machine, and will dry off even the heaviest precipitation of rain in twenty-four hours. If a spring tide soaks the marsh the drainage is slower; but the surface will be free of shallow pools within forty-eight hours.

Lest it should be considered that this is all a statement of belief merely it should be said that in 1903 several bad areas near Newark and Elizabeth were experimentally ditched. When the work was begun the marshes were soft, full of holes, water-logged and hip boots were a necessity. The crop of salt hay could not be gathered until winter and lawn shoes for horses where they could be used at all, were a necessity. Throughout 1904 it was possible to walk over the drained area at all times, dry-shod except after heavy rains, and then twelve hours were enough to dispose of every pool or puddle. The crop of hay was heavier than for many years past, much of it was cut by machine and horses could be taken everywhere. Practically no mosquitoes developed on these areas.

The most convincing work however was done on the Shrewsbury River, extending from Seabright to North Long Branch and including nearly all the marsh area on both Monmouth Beach and Rumson neck sides of the stream. The territory had been roughly surveyed during the season of 1903 under the direction of local associations, and during the winter, at the request of these associations, one of the field agents and afterward an engineer was sent down to lay out a general drainage scheme. Before even the frost was out of the ground work was begun, and very soon afterward, in early March, wrigglers made their appearance in every pool and millions of potential mosquitoes were on the marsh. But the weather remained cold, larval growth was slow and the work was systematically pushed so as to reach the worst places first, the sods removed from the ditches being

used to fill the small deep holes that would naturally drain most slowly. Toward the end of the task in April, it became a race between the ditchers and the insects, which were beginning to pupate. The ditchers won and the last pool was drained before the first adult mosquito issued. It was interesting to watch a new ditch just opened into tide water, flowing in a steady stream toward the outlet and carrying a surface cargo of wrigglers and pupæ; and yet more interesting was it to see the 'killies' at the ditch mouth, taking care of every specimen that came out and gradually running up the ditch to meet them. On these hundreds of acres of meadow not one of the

MACHIN 1 .HING ON THE NEWARK MEADOWS, SUMMER, 1904.

millions of mosquito larvæ came to maturity. On the marshes to the north and south where no work was done, the mosquito output was phenomenal and the early summer of 1904 will be long remembered. Not only the nearby cities and towns were sufferers, but the insects actually crossed both ridges of the Orange Mountains in their travels to the west, and swarmed in the hills about Paterson to the north. And in all this the Shrewsbury River country was practically free from mosquitoes and remained so all summer! There were some local fresh-water species that proved troublesome later in the season; but these were dealt with as fast as their breeding places were located. The marsh mosquitoes that had been the pest of previous years were conspicuous by their absence. A yet greater work was done by the City of Newark, where 3,500 acres of salt marsh were dealt with. No results were apparent in 1904, because the heavy early broods were allowed to develop unchecked; but the marsh is now dry except in a

very small section, and the spring of 1905 should tell an interesting story. There will be some mosquitoes, of course, because of the Elizabeth, Kearny and Jersey City marshes that are so near by. Elizabeth is showing an intelligent interest in the work and has estimates of the cost of clearing up her marsh land, which is not much less than the Newark area. The Kearny meadows at the junction of the Hackensack and Passaic are being filled by immense hydraulic dredges and will soon be not only mosquito free but industrially useful. At a number of other places in the state effective work has been done, and it is now all in the direction of permanent improvement. A

HAND DITCHING ON THE SHREWSBURY RIVER MARSHES, EARLY SPRING OF 1904.

breeding place once eliminated makes a permanent reduction in the supply and is a positive gain.

By an amendment to the health laws passed during the session of 1904, waters in which mosquito larvæ breed are declared nuisances because of that fact alone, and the local boards of health are empowered to deal with them. In a number of places proceedings under this law have produced excellent results.

The investigations made are important as eliminating from consideration vast stretches of supposed breeding grounds like the cat-tail areas in the Hackensack Valley; as limiting the number of species which must be dealt with; as showing clearly the natural checks that may be practically utilized; as proving to demonstration that control amounting to practical extermination is not only possible, but not even difficult; and finally as furnishing a scientific basis for practical work.

THE PROGRESS OF SCIENCE.

THE PRESIDENCY OF THE CARNEGIE INSTITUTION.

PROFESSOR ROBERT SIMPSON WOODWARD, who holds the chair of mechanics and mathematical physics at Columbia University and is dean of the faculty of pure science, was elected president of the Carnegie Institution at the meeting of the trustees held at Washington on December 13. No selection could have been made more certain to meet the general approval of scientific men. They know that Professor Woodward possesses in an unusual degree the scientific eminence, executive ability, sound judgment and sympathetic personality which the position requires. His own researches have given him acquaintance with a wide range of the sciences, he having made contributions to mathematics, physics, geology and astronomy, while he has an intelligent interest in the biological sciences. He has been president and is now treasurer of the American Association for the Advancement of Science; he is a member of the National Academy of Sciences; he has been president of the American Mathematical Society and of the New York Academy of Sciences; he is one of the editors of *Science;* he has always done far more than his share to promote all efforts for the advancement of science.

The presidency of the Carnegie Institution is the most important scientific position in the world. There are attached to this office unusual opportunities and at the same time serious responsibilities. As our readers know, Mr. Andrew Carnegie gave three years ago preferred bonds of the United States Steel Corporation of the par value of $10,000,000 to establish at Washington an institution whose objects are defined in the articles of incorporation, as follows:

(*a*) To acquire, hold and convey real estate and other property necessary for the purposes of the Institution as herein stated, and to establish general and special funds;

(*b*) To conduct, endow and assist investigation in any department of science, literature or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies and individuals;

(*c*) To appoint committees of experts to direct special lines of research;

(*d*) To publish and distribute documents;

(*e*) To conduct lectures;

(*f*) To hold meetings;

(*g*) To acquire and maintain a library;

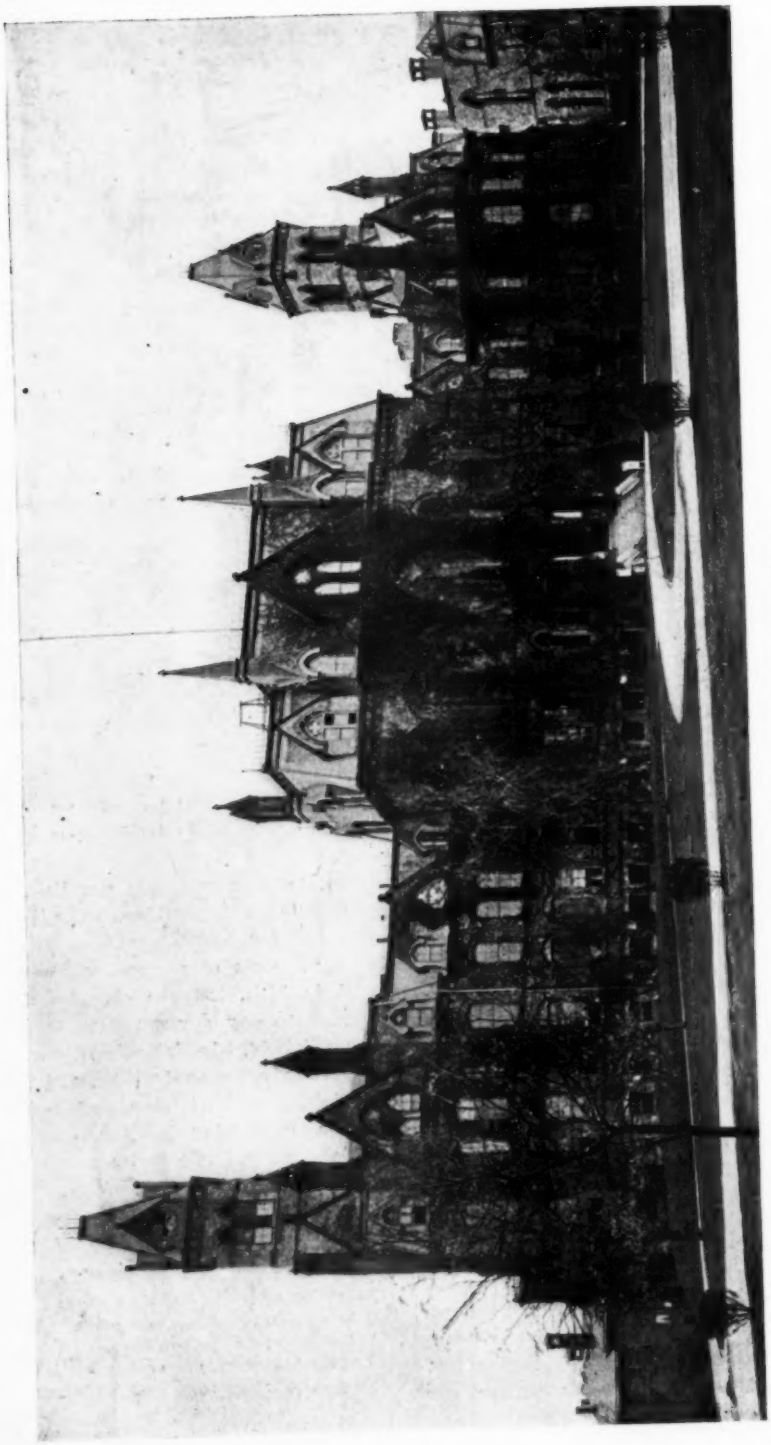
(*h*) And, in general, to do and perform all things necessary to promote the objects of said institution.

It is not remarkable and it is perhaps fortunate that three years have elapsed without committing the institution to any definite policy. Smithson's bequest 'to found at Washington an establishment for the increase and diffusion of knowledge among men' was in its objects closely parallel to Mr. Carnegie's foundation. The legacy of about $550,000 was received in 1838. All sorts of projects were embodied in bills, but the congress did not come to any agreement as to its uses until 1846. The delay in this case was certainly fortunate. Soon after the establishment of the Carnegie Institution a number of the leading American men of science took part in a discussion published in *Science* on its functions, which were summarized in the New York *Independent* in the following conflicting propositions:

1. Establish large and well-equipped laboratories at Washington for each science.

2. Waste no money on buildings, but utilize existing laboratories wherever they may be.

3. Keep young men from deserting scientific pursuits by granting numerous fellowships to poor but worthy persons.



COLLEGE HALL, UNIVERSITY OF PENNSYLVANIA.

4. Give no fellowships, but, on the contrary, charge high tuition.

5. Give small sums to many individuals.

6. Money distributed in small amounts is wasted. Give at least $100,000 at a time.

7. Assist unknown and struggling men in small colleges.

8. Make no grants except to tried and proved investigators.

9. Grant only for specific purposes and on definite lines of work.

10. Give the investigator perfect freedom because he can not tell what he is going to discover beforehand, and would not be willing to publish his intentions.

11. Pay salaries of $10,000 a year to the leaders of each science.

12. Expend no money on salaries, but supply only apparatus and books.

13. Publish a handsome series of quarto and folio memoirs.

14. Waste no money on big books and wide margins.

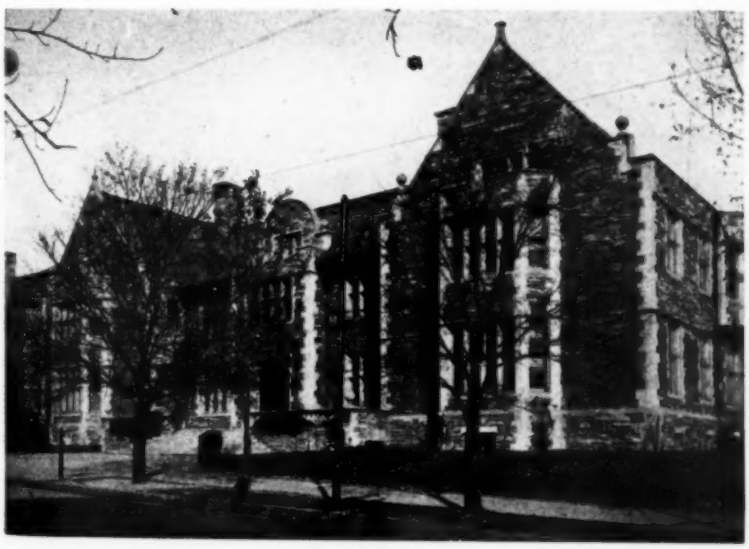
15. Grant degrees and award prizes.

16. Grant no degrees and offer no prizes.

This represents in somewhat exaggerated form the diversity in the views of scientific men; and when there are such differences of opinion, it is wise to move slowly in adopting an irreversible policy. There are possibilities that appeal to the imagination in an institution that can play the part of a special providence throughout the country, scattering money just where it will bring forth fruit a hundredfold and discovering the struggling genius to give him the work he is best fitted to do. But there are difficulties and even dangers in such an undertaking. Under its new president the Carnegie Institution will be in a far better position than hitherto to carry out a policy of this kind. But it is probable that the institution will ultimately become one of the constituents of a great national university.

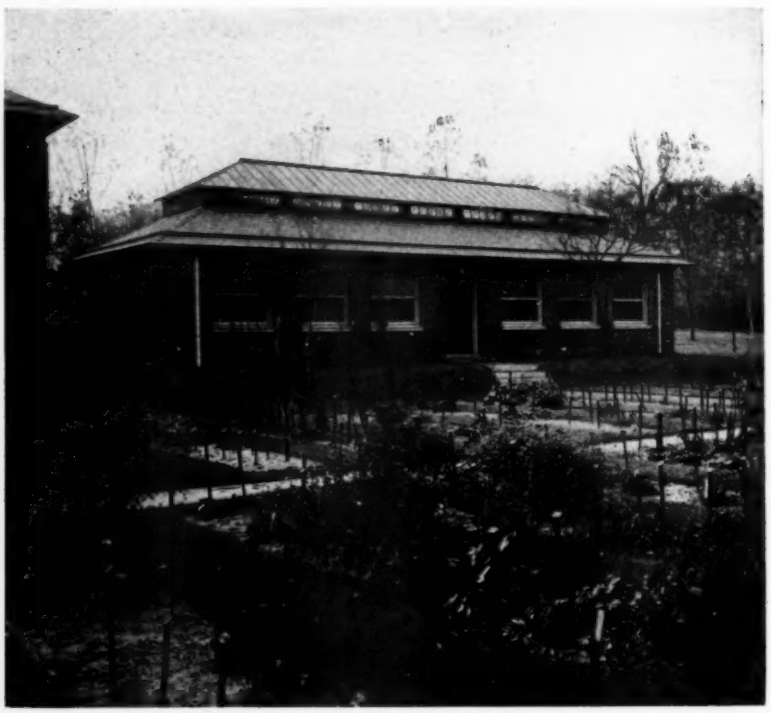
CONVOCATION WEEK AT THE UNIVERSITY OF PENNSYLVANIA.

THE American Association for the Advancement of Science held its first meeting in Philadelphia in 1848. After an interval of thirty-six years it met for the second time in Philadelphia in 1884, when the attendance was 1,261. This was the largest meeting in the history of the association, but the numbers were increased by 303 members of the British Association, which met that year in Canada. At the Boston meeting of 1880 there were 997 and at the Montreal meeting of 1882 there were 937 members in at-



HOUSTON HALL.

THE NEW MEDICAL LABORATORIES.



THE VIVARIUM AND BOTANICAL GARDEN.

tendance. These meetings represent a culminating point in the history of the association, and an important epoch in the development of science. Until 1882 there were only two sections of the association, one for the exact sciences and one for the natural sciences. But at about this period specialization and differentiation became imperative. The conditions were in part met by dividing the association into sections, but more adequately by the establishment of special societies. The American Society of Naturalists was organized in 1883, and has since held winter meetings, the membership being confined to professional students of the natural sciences. The American Chemical Society had been established in 1876; the Geological and Mathematical Societies were organized in 1888. Since that time special societies have been founded for all the leading sciences, and there is a tendency for them to divide into branches for the different sections of the country.

The establishment of these special societies represents an important advance, but its first effect was to weaken the parent association. Professional men of science found the amateur element too prominent in the summer meeting and the time was inconvenient for many of them. In spite of the great increase in the numbers of scientific men in the country, the meetings became smaller and the membership decreased. But this was only a temporary phase. The interests of men of science are not exactly limited by the conventional bounds of a single science. A zoologist, for example, may be interested in anatomy, physiology, pathology, paleontology, geography, botany, psychology, chemistry or some other science. It is also the case that those who attend the annual meetings like to see their friends from other parts of the country who may be working in fields remote from their own. It is advantageous consequently for the special societies to meet in groups at times,

THE RANDEL MORGAN LABORATORY OF PHYSICS.

THE FLOWER ASTRONOMICAL OBSERVATORY.

even though they may like occasionally to be isolated, and some machinery is necessary to make local arrangements, to secure reduced railway fares and the like.

Then while a small group of experts is the ideal condition for the presentation and discussion of special research, there are wider aspects of science and interrelations between the sciences for the adequate consideration of which workers in different departments must come together. There are also conditions of scientific progress, such as educational methods, scientific institutions, publication, government activities, etc., that need criticism and control. Neither trades unions nor corporations meet with universal approval at the present time, but it is obvious that some union among men of science is desirable for the support of their common interests, which in this case are fortunately identical with the interests of society. Lastly a federation of societies and a large gathering of scientific men is an important factor in keeping scientific work in touch with the outside world and in impressing on it the unity and weight of scientific research.

The complicated conditions appear to have been met by the establishment of 'convocation week' at the end of the Christmas holidays. Under the general auspices of the American Association arrangements are made at some large center for the meeting of the association and of the special societies that care to join with it. The special societies have complete control of their place and time of meeting, of their programs and membership; but without interfering with their autonomy the advantages of a great gathering of scientific men are assured. Thus at Philadelphia, beginning the day after Christmas, there will meet the American Association and its ten sections; the American Society of Naturalists, and some twenty special societies, including those devoted to astronomy, physics, chemistry, geology, botany, zoology, paleontology, bacteriology, physiology, anatomy, anthropology, psychology and philosophy.

The societies are fortunate in their

place of meeting this year. Philadelphia is centrally situated, at least for the Atlantic seaboard. The city is noted for its scientific societies and institutions. The University of Pennsylvania is one of the great universities which can offer admirable accommodations to all the societies and at the same time much to interest all men of science. Houston Hall, the beautiful club house of the students, will be an admirable center for social intercourse. The magnificent new medical laboratories will not only give excellent places of meeting for the societies devoted to the biological sciences, but a visit to them would repay a trip from Boston or even from Chicago. Each group of scientific men will find something to interest them in the advances made by the university during the ten years of Provost Harrison's administration. These include the laboratories of physics and of chemistry, the engineering hall, the observatory, the botanical garden, the vivarium and the museums, to mention only certain of the developments connected with the natural and exact sciences.

THE U. S. DEPARTMENT OF AGRICULTURE.

MUCH has been written of late about the work of the National Department of Agriculture, and widespread public interest aroused in its developments. There have been occasional criticisms of particular investigations, but there has been much to commend, which has appealed to people as having an important bearing in the development of agriculture. Interest in its annual report is by no means confined to the farmers and horticulturists, and no one can read it without being impressed by the fact that under the direction and stimulus of the present secretary of agriculture it has become an agency of great activity and aggressiveness in all that pertains to agricultural science and practise.

No reasonable expense or effort is evidently being spared to introduce or originate plants of improved quality, or better adapted to particular sections, to find remedies for diseases and pests of plants and animals, to extend the market for agricultural products, and to bring about an improved and more intelligent agriculture. In this the department is ably seconded by the agricultural experiment stations, located in every state and territory of the union, whose services the secretary acknowledges in the opening clause of his report and elsewhere. Many of the investigations reported from the department have originated and been worked out at the experiment stations, but they have been fostered and exploited by the department. Much of this work is a joint undertaking. The relations between these agencies are so close in object and method that specific reference to the stations is not made in each case, although evidently implied in a summary of what has been accomplished. The secretary endorses the movement for increasing the federal appropriation to the state stations, a bill for which is now pending in congress, and commends their work unsparingly.

Among the exigencies of the year which have called for special attention are the control of cattle scab and mange in the west, of which the individual states were unable to prevent the spread, and the serious and threatening ravages of the cotton-boll weevil in Texas and Louisiana. The latter work has been widely described in the press. The past season was a favorable one in bringing out the value of macaroni or durum wheats, introduced by the department in the semi-arid west a few years ago. It is estimated that fourteen million bushels were grown, and a great impetus was given to their culture. The growing of pedigreed sugar beet seed is showing home-grown seed to be equal to the imported seed, and often better. A

sweet orange of the hardy type, produced by crossing, is thought to give promise; and breeding and selection work is being carried on with tobacco to improve the leaf. Much-needed studies have been made upon the cold storage of fruit, to determine the conditions of growing, picking and handling for that purpose and for export. During the year over fourteen hundred kinds of seeds and plants were introduced, through agricultural explorers and correspondence, from various parts of the world. In this line special attention is being paid to the development of dry-land farming in the west. Evidence is presented of the value of copper sulphate for ridding water supply of obnoxious algæ, and progress is reported in the direction of making practically useful the important discoveries of Hellriegel, Wilfarth and others as to the assimilation of nitrogen from the air by plants with the aid of certain bacteria. An important new line of work is that relating to the breeding of animals, which has been undertaken on a systematic basis in co-operation with the experiment stations and with a special appropriation from congress.

In the investigations on human nutrition, the respiration calorimeter has been developed to a point of high scientific accuracy, and is being employed in studies on the comparative value of fat and carbohydrates as sources of energy to the body. Investigations have been completed on the much-agitated question of the value of the whole-wheat and graham flours as compared with ordinary flours, and dietary studies made at public institutions. Laboratories have been established for the inspection of imported food products, the character of which has greatly improved under this inspection; and investigations nave been made of the effect upon health of food preservatives, such as borax. The irrigation investigations have had to do especially with the water requirements of crops, the economy of water, method of applying it, and pumping trials. Drainage investigations have been added, to include the large drainage problems growing out of the formation of marshes from irrigation, reclamation of the everglades of Florida, tidal marshes, etc.; and it is urged that this work in agricultural engineering be extended to include farm buildings and farm machinery, upon which there is much call for expert information.

The publications of the department, which reflect its activity and growth last year, reached the large number of 972 separate documents, the editions of which aggregated nearly twelve and a half million copies. Nearly half of these were 'farmers' bulletins' of popular character. A constantly increasing demand is noted for the department's publications by educational institutions, to be used for class work; and two thirds of the publications sold by the superintendent of documents were those of the Department of Agriculture. This attests the increasing appreciation of its work.

The generally optimistic character of the report indicates a commendable faith and enthusiasm in the work which the department is doing, and in the ability of science to solve many of the problems which now confront the agriculture of this country.

THOMAS MESSINGER DROWN.

By the untimely death of Thomas Messinger Drown, LL.D., on November 16, Lehigh University has lost a wise and beloved president, and American science a versatile and accomplished chemist, while a large circle of friends mourns the loss of a singularly winning personality, always cheerful, gentle, kindly and helpful. Dr. Drown was born on March 19, 1842, at Philadelphia. After graduating in medicine at the University of Pennsylvania, he pursued graduate studies in chemistry under

W. M. Flickinger, Photographer.

THOMAS MESSINGER DROWN.

leading American and German masters. For seven years he occupied the chair of analytical chemistry at Lafayette College, and for ten years a similar chair at the Massachusetts Institute of Technology. One of the founders of the American Institute of Mining Engineers, he served with conspicuous efficiency for ten years as its first secretary and editor of its *Transactions*, being later elected to honorary membership and in 1897 to its presidency. Dr. Drown did important original work in quantitative analysis in two directions. In metallurgy he devised methods which have become standard in the analysis of iron and steel. In sanitary chemistry he introduced improvements both in the methods and in the interpretation of water analysis. As chemist in charge of the investigation of the natural waters of Massachusetts, he instituted a series of investigations which resulted, among other things, in the unique map showing the distribution of 'normal chlorine' in the springs and wells of the entire state. Dr.

Drown was consulting chemist to the Massachusetts State Board of Health till the time of his death.

In 1895 Dr. Drown was called to the presidency of Lehigh University at a time when that institution's influence was at a low ebb. With rare courage and a faith in the institution, since justified by events, he restored to the university its own wavering faith and waning courage, gave it a good business administration, widened its educational horizons, and, by his sympathetic, intelligent guidance, fostered the steady, healthful growth characteristic of recent years.

During President Drown's administration the number of students has been increased from 325 to 650. The teaching staff has been proportionally increased and the grades of assistant professor and assistant, characteristic of modern university organization, have been introduced. Mineralogy and metallurgy have been divided into independent departments; likewise geology has been separated from mining, and electrical engineering from physics. A department of biology, inclusive of bacteriology, has been established, with adequate laboratory equipment, and a department of economics and history, intended equally for students in engineering and in arts. The department of philosophy and psychology, formerly an adjunct to the chaplaincy, has been given its independence, a psychological laboratory and courses in pedagogy being added. Hand in hand with President Drown's policy of expansion and differentiation went that of correlation. The School of General Literature has grown steadily by the side of the technical schools, which in turn have been increasingly hospitable to the introduction of liberal studies. Dr. Drown had long cherished a plan to evolve a six-year course fitted to furnish both a broad culture and an adequate training for the professional work of the engineer.

SCIENTIFIC ITEMS.

It is reported that Nobel prizes will be awarded to Sir William Ramsay in chemistry and to Lord Rayleigh in physics. — The Royal Society has awarded its Rumford medal to Dr. Ernest Rutherford, professor of physics at McGill University, for his researches on radio-activity.

Professor Charles A. Young, who celebrated his seventieth birthday on December 15, will retire from the chair of astronomy at Princeton University at the close of the present year and will become professor emeritus. — Dr. George H. Howison, professor of philosophy in the University of California, celebrated his seventieth birthday on November twenty-fifth, when he was presented with a *Festschrift* prepared by his former students.

During the recent excursion of the Eighth International Geographic Congress to the Grand Canyon of the Colorado in Arizona, a meeting was held in memory of Major J. W. Powell, in which his exploration of the canyon, his western surveys and his work as director of the United States Geological Survey and as organizer of the Bureau of Ethnology were briefly described. At the close of the meeting it was resolved to erect a monument in memory of Powell on the edge of the plateau overlooking the Grand Canyon.